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DIODE

STEP STRESS TESTING PROGRAM

MSFC/NASA CONTRACT NUMBER NAS8-31944

> FINAL REPORT FOR JANTX 1N3016B

FEBRUARY 1979

Prepared For

GEORGE C. MARSHALL SPACE FLIGHT CENTER NATIONAL AERONAUTICS AND SPACE ADMINISTRATION Marshall Space Flight Center, Alabama 35812



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RELIABILITY LABORATORY

DCA RELIABILITY LABORATORY SPECIAL PRODUCTS DIVISION 975 BENICIA AVE SUNNYVALE, CALIFORNIA 94086

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.

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1 Miles

JANTX1N3016B

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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 <u>Electrical</u>

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 <u>Stress Circuit</u>

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

<u>Group I - Power Stress</u>

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 <u>Siemens</u>. 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 ^IR leakage. Serial number 2259 failed the minimum ^BV limit. Serial numbers 2254, 2256, 2257, 2258, 2260, 2261, 2262, 2265, 2266, 2267, 2268 and 2269 failed the maximum ^BV 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 <u>Motorola</u>. 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 ^IR leakage. The next failure occurred 50 hours into the 125% MRP step. Serial number 2207



failed the maximum ^BV limit. The next failure occurred 250 hours into the 125% MRP step. Serial number 2205 failed due to excessive ^IR 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 ^BV limit. Serial number 2215 failed the minimum ^BV 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 ^IR leakage. Typical characteristics of this sample lot's performance were:

 The mean value for ^IR changed
 1.114mA from an initial mean of 4.398µA to a final mean of 1.118mA.
 The mean value for ^BV 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 <u>Statistical Summary - Group I</u>. 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 <u>Siemens</u>. 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 ^BV limit. The next five failures occurred 160 hours into the 200[°]C-temperature step. Serial number 2285 failed due to excessive ^IR leakage. Serial number 2285 failed due to excessive ^IR leakage. Serial numbers 2273, 2282, 2283 and 2284 failed the maximum ^BV limit. The last nine failures cocurred 16 hours into the 2250C-temperature step. Serial numbers 2270, 22771, 2273, 2274, 2276, 2277, 2278, 2279 and 2200 failed the maximum ^BV limit. Typical characteristics of this sample lot's performance were:

 The mean value for ¹R changed
 196.4µA from an initial mean of 1.297µA to a final mean of 197.7µA.
 The mean value for ^BV 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 <u>Motorola</u>. 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 ^BV limit. The next three failures occurred 160 hours into the 200°C-temperature step. Serial number 2227 failed because of excessive ^IR leakage. Serial number 2228 failed the maximum ^BV limit. Serial number 2229 failed the minimum ^BV 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 ^IR leakage. Serial numbers 2218, 2220, 2221, 2223 and 2232 failed the maximum ^BV limit. Typical characteristics of this sample lot's performance were:

 The mean value for ^IR changed
 4.989mA from an initial mean of 5.715µA to a final mean of 4.995mA.
 The mean value for ^BV 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 <u>Statistical Summary - Group II</u>. 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 <u>Siemens</u>. 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 ^BV 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 ^BV limit. Typical



characteristics of this sample lot's performance were:

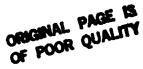
1) The mean value for ^IR changed 4.001 μ A from an initial mean of 1.530 μ A to a final mean of 5.531 μ A.

2) The mean value for ^BV 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.

Motorola. The Motorola sample lot completed the 3.3.2 entire 112-hour Group III Testing with six catastrophic failure. The first two failures occurred 15 hours into the 200°C-temperature step. Serial number 2241 failed the minimum ^BV limit. Serial number 2243 failed because of excessive ^IR leakage. The next failure occurred 16 hours into the 225⁰C-temperature step. Serial number 2248 failed due to excessive ^IR leakage. The next failure occurred 15 hours into the 275°C-temperature step. Serial number 2235 failed because of excessive ^IR leakage. The last failures occurred 16 hours into the 309°C-temperature step. Serial number 22400 failed the minimum ^BV limit. Serial number 2246 failed the maximum ^BV limit. Typical characteristics of this sample lot's performance were:

> The mean value for ^IR changed
> 843.5µA from an initial mean of 552.lnA to a final mean of 844.lµA.
> The mean value for ^BV 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 <u>Statistical Summary - Group III</u>. 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



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

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

Where: $t_1 = step of Group || - Temp Stress | = 160 hrs.$ $<math>t_2 = step of Group ||| - Temp Stress || = 16 hrs.$ $<math>T_1 = temperature in {}^{O}C of 16\%$ failure for Group ||. $T_2 = temperature in {}^{O}C of 16\%$ failure for Group ||].

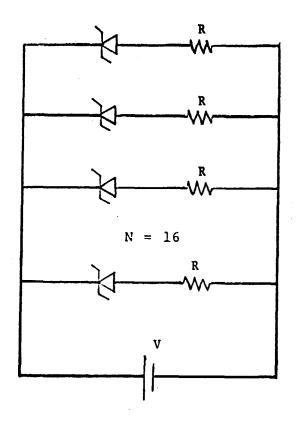


NOTE:

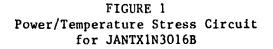
- * Conditions for failure:
 - A) Open or short
 - B) Leakage exceeds the maximum limit by 100 times.
 - C) Other parameters exceed MIL limits by 50% or more.

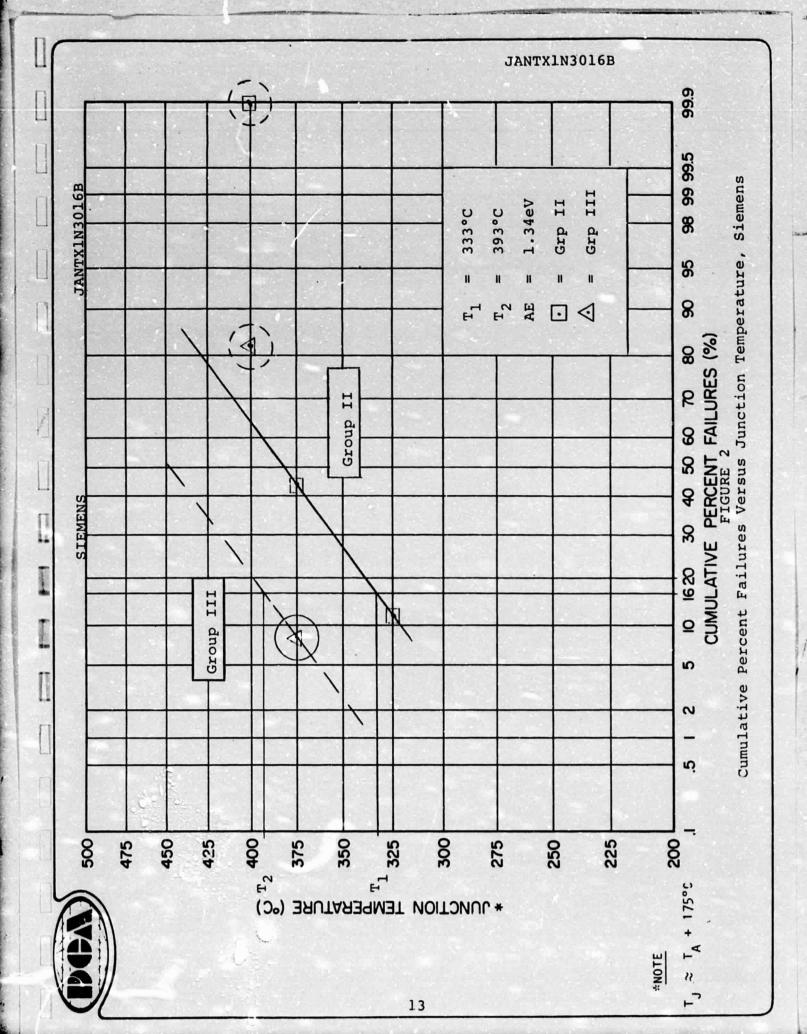


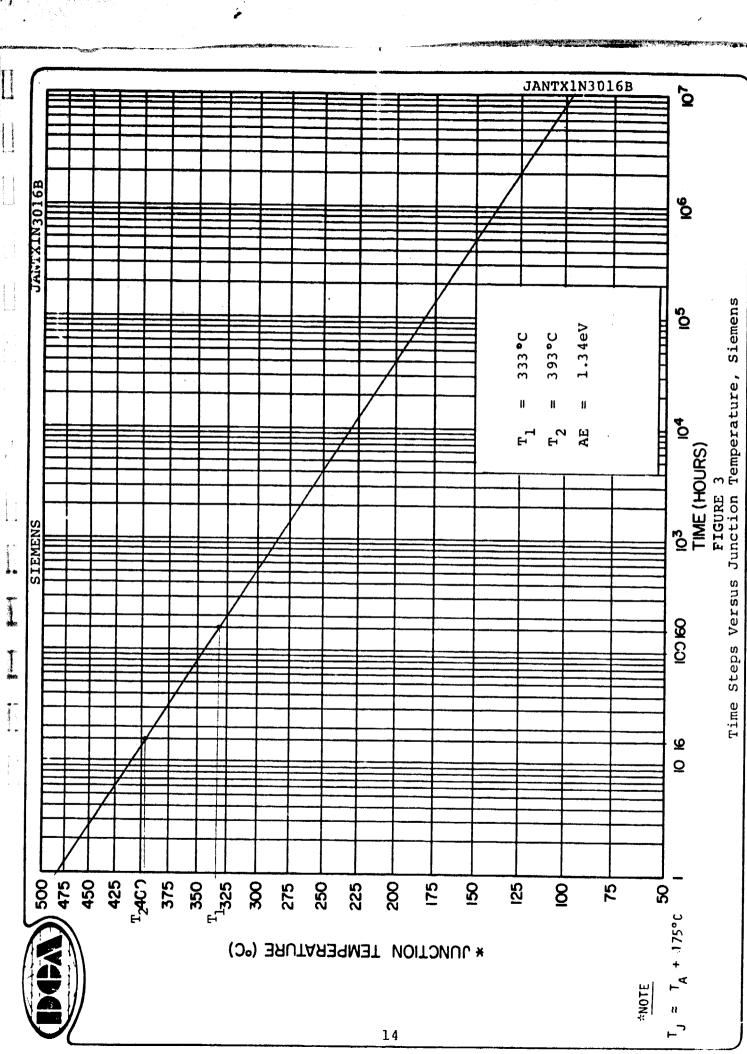
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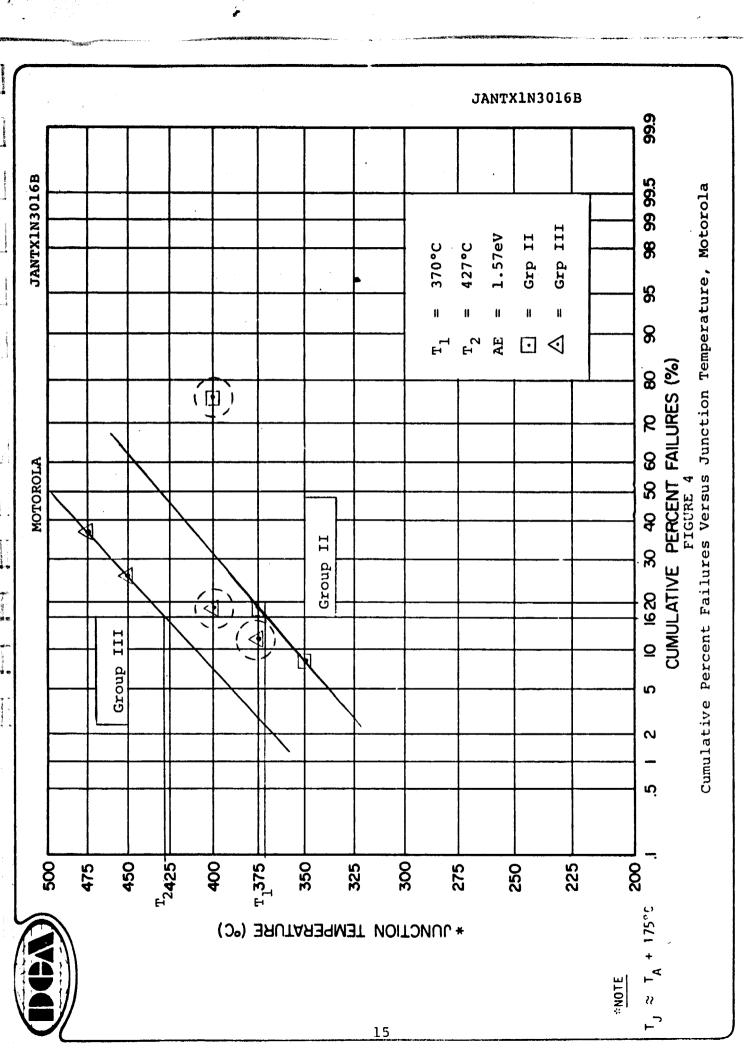


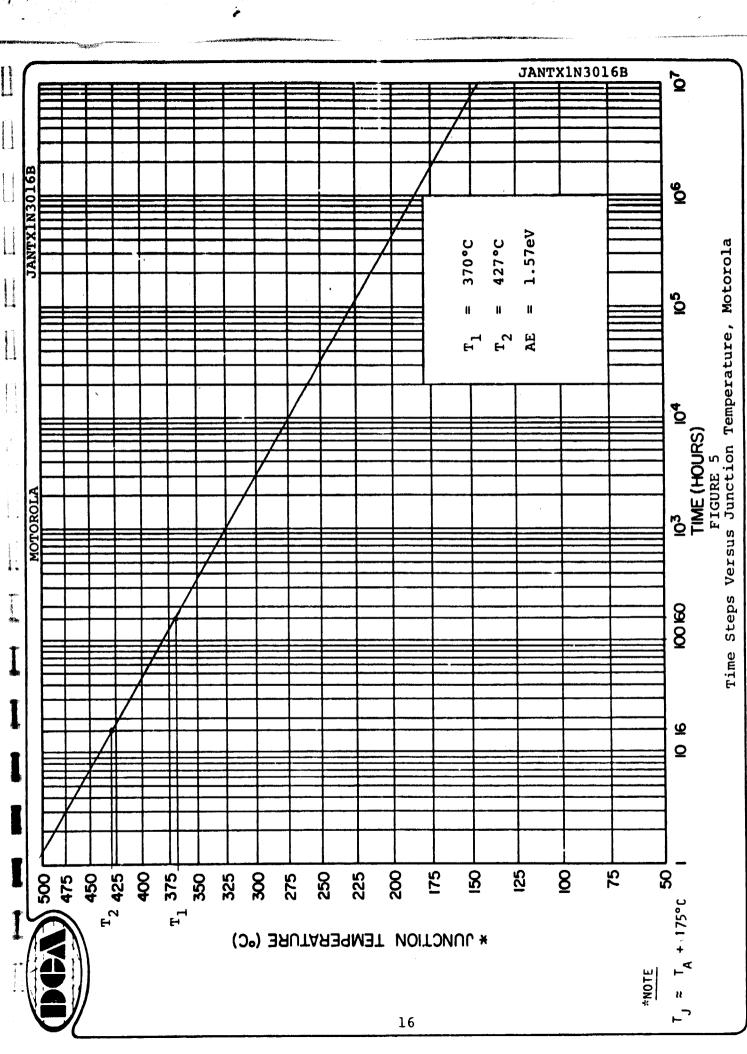
 $R = VZ \div 1.75 IZ_{MAX} \pm 50\%$ $P_{d} = VZ^{2} \div R$

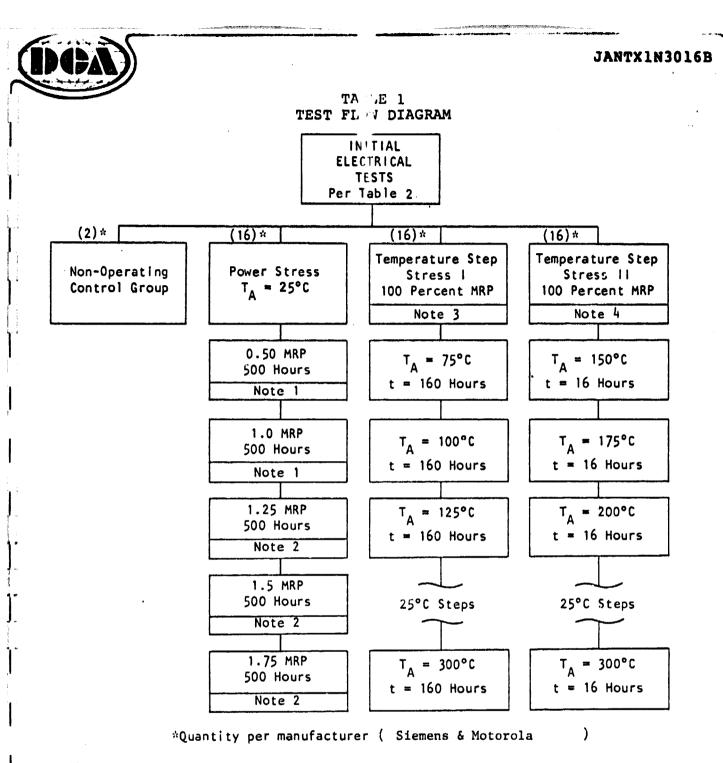












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NOTES:
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Electrical measurements per Table 2 were made at 50, 150, 250 and 500 hours.
 Electrical measurements per Table 2 were made at 10, 25, 50, 150, 250 and 500 hours.
 Electrical measurements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

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JANTX1N3016B

	TAB	.it 2	
PARAMETERS	AND	^{••} EST	CONDITIONS

		SPEC.	LIMIT	CAT.	LIMIT	
PARAMETER	CONDITIONS	MIN	MAX	MIN	MAX	UNITS
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:		<u>_</u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>

TABLE 3 POWER STRESS BURN-IN CONDITIONS

V _Z =	6.8v
IZ	Percent P _D
73.5mA	50
147.OmA	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.

PARAMETR I_R = 150ux (text) B_V^{-6} , 46V (ritts) T_A^{-6} (46V (ritts) T_A^{-6} (46V (ritts) T_A^{-6} (46V (ritts) T_A^{-6} CONDITIONS AND LINIT Ψ_R = 5.2V I_Z = 37.0mA I_Z = 37.0mA I_Z = 37.0mA DEMITIFICATION SIE MOT SIE MOT SIE MOT DEMITIFICATION SIE MOT SIE MOT SIE MOT NINITIAL DRIN 35.10mA 5.200mA 6.519V 6.518V MOT SIE MOT NINERIN MALIE 35.10mA 5.400MA 1.2.08MA 1.2.00MV 7.000V SIE MOT MITERIN MALIE 5.35.10mA 1.22.00mV 1.22.00mV 1.2.00mV SIE MOT SIE MOT SIE MOT SIE			GROUP I	TABLE - POWER S'	JE 4 Stress data summary	MARY Page 1 of 2
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1253 13.98uA 152.3mV 147.6mV - 1253 68.50hA 1.578uA 3.000mV -5.000mV - 77.90hA 1.578uA 3.000mV -5.000mV -4.000mV - 80.60hA 1.578uA 1.900mV -2.000mV -2.000mV - 80.60hA 1.674uA 0V -2.000mV -2.000mV - 81.90hA 1.674uA 0V -2.000mV - - 81.90hA 1.674uA 0V -2.000mV - - 81.90hA 1.674uA 0V -4.000mV - - 50.20hA 7.324uA 1.000mV -3.000mV - - 51.00hA 7.342uA 1.000mV - - 0V 51.10hA 7.342uA 1.4.000mV - - 0V 51.10hA 7.342uA 1.5.00mV - 0V 0V 51.510hA 23.02uA 15.00mV - 0V 0V 51.510	MEAN	643. 5nA	4.398µA	6.696V	6.820V	
1253 1.578uA 1.578uA 1.578uA 3.000mV -5.000mV -4.000mV -4.	STD DEV	545.3nA	13.98µA	152.3mV	147.6mV	
8 50 T0 1253 NW VALUE OWER 68.50hA 1.578uA 3.000mV -5.000mV POWER 68.50hA 1.578uA 3.000mV -5.000mV RS 80.60hA 1.920uA 4.000mV -4.000mV HRS 80.60hA 1.674uA 0V -1.000mV HRS 83.90hA 1.674uA 0V 1.000mV HRS 31.80hA 99.00hA 1.000mV -3.000mV POVER 7.332uA 1.000mV -3.000mV -3.000mV HRS 50.20hA 7.532uA 1.000mV -3.000mV HRS 50.20hA 7.532uA 1.000mV -3.000mV HRS 50.20hA 7.532uA 1.000mV -3.000mV HRS 50.20hA 7.374N 1.000mV -3.000mV HRS 50.20hA 7.374N 1.000mV -3.000mV HRS 50.20hA 13.68hA 13.00mV -0.00mV HRS J08 7.374V -7.000mV -1.000mV HRS J08 10.00mV -3.000mV -1.000mV HRS J08 10.00mV -3.000mV -3.000mV HRS J08 10.00mV -3.000mV -3.000mV	INTERIM DATA					
OVER And the state 1:578uA 1:578uA 1:578uA 1:578uA 1:578uA 1:578uA 1:578uA 1:000mV -4:000mV -1:000mV -1	POWER 50 TO 1253 A MEAN VALUE					
HRS 68:50ha 1:578ua 3:000mV -5:000mV -2:000mV -2:000mV -2:000mV 1:000mV -2:000mV -2:0	50% POWER					
HS 77.90nA 1.920µA 4.000mV -4.000mV HRS 80.66nA 1.920µA 4.000mV -2.000mV HRS 83.90nA 1.674µA 0V 1.000mV -2.000mV HRS 31.80nA 99.00nA 1.000mV -4.000mV 4.000mV HRS 63.10nA 7.532µA 1.000mV -3.000mV 4.000mV HRS 63.10nA 7.532µA 1.000mV 4.000mV 4.000mV HRS 63.10nA 7.532µA 1.000mV 0V 0V 00 HRS 1.630µA 13.68µA 7.374V -3.000mV 4.000mV HRS 1.630µA 13.68µA 00 HRS 1.630µA 13.68µA 00 HRS 1.630µA 13.68µA 00 HRS 1.630µA 13.68µA 7.374V -7.000mV HRS 1.630µA 13.68µA 7.374V -7.000mV HRS 1.630µA 13.68µA 00 HRS 1.630µA 13.68µA 7.374V -7.000mV HRS 1.630µA 13.68µA 7.374V -7.000mV HRS 1.630µA 13.68µA 7.374V -7.000mV HRS 1.630µA 13.68µA 7.374V -7.000mV		68.50nA		3.000mV	-5.000mV	
HRS 80.60nA 1.603uA 0V -2.000mV 1.603uA 0V 1.000mV 1.603uA 0V 1.000mV 1.603uA 0V 1.000mV		77.90nA	1.920µA	4.000mV	-4.000mV	
HKS 03.300A 1.074.4A 0V 1.000mV 1.000mV POWER 31.80nA 99.00nA 0V -4.000mV -1.000mV HRS 50.20nA 7.532uA 1.000mV -3.000mV -3.000mV HRS 50.20nA 7.532uA 1.000mV -4.000mV -3.000mV HRS 63.10nA 7.342uA 14.00mV -3.000mV -3.000mV HRS 63.10nA 7.342uA 15.00mV -0.00mV -3.000mV HRS 694.5nA 23.02uA 15.00mV 0V -0.00mV POWER *1.630mA 13.68uA 7.374V -7.000mV -0.00mV HRS J0B STOPPED 14.05uA J0B STOPPED -10.00mV -10.00mV HRS J0B STOPPED 14.65uA -3.00mV -7.000mV -7.000mV HRS J0B STOPPED 14.05uA J0B STOPPED -10.00mV -9.00mV HRS J16.65uA 16.47uA -10.00mV -10.00mV -10.00mV		80.60nA	1.603µA	N 0	-2.000mV	
POWER 31.80nA 99.00nA 0V -4.000mV -4.000		63. YUNA	1.0/4+A	5		
HRS 31.80nA 99.00nA 0V -4.000mV HRS 50.20nA 7.532uA 1.000mV -3.000mV HRS 63.10nA 7.342uA 1.000mV 4.000mV HRS 694.5nA 23.02uA 15.00mV 4.000mV POWER *1.630mA 13.68uA 15.00mV 0V HRS JOB STOPPED 13.68uA 13.58uA 13.74V -7.000mV HRS 13.68uA 13.68uA 10B STOPPED -10.00mV HRS 15.00mV 4.000mV HRS 15.00mV 4.000mV HRS 15.00mV 4.000mV HRS 4.654uA 10B STOPPED -10.00mV HRS 4.654uA 10B STOPPED -10.00mV	100% POWER					
HRS 50.20nA 7.532µA 1.000mV -3.000mV HRS 63.10nA 7.342µA 14.00mV 4.000mV HRS 694.5nA 23.02µA 15.00mV 0V 4.000mV POWER *1.630mA 13.68µA 7.374V -7.000mV HRS JOB STOPPED 14.05µA JOB STOPPED -10.00mV HRS 15.36µA 7.374V -7.000mV HRS 4.888µA 13.68µA 7.374V -7.000mV HRS 4.654µA 90 5.00mV HRS 4.654µA 90 5.00mV HRS 4.654µA 90 5.00mV		31.80nA	99.00nA	V 0	-4.000mV	
HKS 694.5nA 23.02µA 14.00mV 4.000mV HKS 694.5nA 23.02µA 15.00mV 0V 0V/ER *1.630mA 13.68µA 7.374V -7.000mV HKS JOB STOPPED 14.05µA JOB STOPPED -10.00mV HKS HKS 4.68µA -3.00mV HKS 4.654µA -3.00mV HKS 4.654µA -3.00mV HKS -4.00mV		50.20nA	7.532µA	1.000mV	-3.000mV	
POWER *1.630mA 13.68uA 7.374V -7.00mV -7.000mV HRS JOB STOPPED 14.05uA JOB STOPPED 14.00mV -7.000mV HRS JOB STOPPED 14.47uA -10.00mV -7.000mV HRS 14.47uA -10.00mV 0V HRS 14.47uA -10.00mV 0V HRS 15.36uA -9.00mV -9.00mV HRS -14.60mV -3.00mV -10.00mV		63. I UnA 694. 5nA	73.024A	15,00mV	4. 00 0V	
POWER *1.630mA 13.68uA 7.374V -7.000mV -7.000mV HRS JOB STOPPED 14.05µA JOB STOPPED 14.05µA JOB STOPPED -10.00mV HRS JOB STOPPED 14.47µA JOB STOPPED -10.00mV 00 HRS 14.47µA JOB STOPPED -10.00mV -10.00mV 01 HRS 14.47µA 00 01 01 01 HRS 4.888µA -3.00mV -3.00mV -3.00mV 01 HRS 4.654µA -4.00mV -4.00mV -4.00mV -4.00mV -4.00mV						
HRS #1.630mA 13.68µA 7.374V -7.000mV HRS JOB STOPPED 14.05µA JOB STOPPED -10.00mV HRS 14.47µA HRS 15.36µA HRS 4.888µA HRS 4.654µA HRS 4.654µA HRS -4.00mV						
HRS JOB STOPPED 14.05µA JOB STOPPED -10.00mV HRS HRS 14.47µA HRS 15.36µA HRS 4.888µA HRS 4.654µA HRS -8.00mV -4.00mV		*1.630mA	13.68µA		-7.000mV	
HRS I5.36µA -3.00mV HRS 4.888µA -8.00mV HRS 4.654µA -4.00mV		JOB STOPPED	14.05µA 14.47µA		-10.00mV	
HRS 4.888µA -8.00mV -8.00mV HRS 4.654µA -4.00mV			15.36µA		-3.00mV	
			4.888µA		-8.00mV	
	_	* * -	V1+C0.+	*		

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10ENIXINAL	Page 2 of 2																						J		ĪXI	11	- 1 4			
	4ARY																													com data after this point
	(Cont'd) R STRESS DATA SUMMARY	(MIN) 7.14(MAX)	37.0mA	MOT		6.518V		147.6mV					-5.00mV	1.000mV			17.00mV		14.00mV				LIOB STOPPED				7.778V	V295V		: reject(s) removed from data
n an	TABLE 4 - POWER	B _V =6.46V (MIN)	I _Z = 37	SIE		6.519V	0.000 V	152.3mV										 -						>		2.000mV	17.12V	14.07V	vcuc.c	atastrophic
	GROUP I	(MAX)		MOT		52.80nA	4.398µA	13.96µA					3.329µA	3.096µA	3.693µA	2.000µA	6.922µA		4.102µA	4.123µA	5.642µA	AUC.084	TOR STOPPEN			0.000A	9.990mA	1.118mA	3.13/84	* NOTE: Ca
	sheet)	I _R = 150μA(MAX)	@ V _R = 5.2V	SIE		35.10nA	2.2/04A	543.3nA															·	> >		0.000A	9.990mA	1.631mA	3.487mA	
	from first she	•	CONDITIONS AND LIMITS	IDENTIFICATION	INITIAL DATA	MIN VALUE	MEAN	STD DEV	INTERIM DATA	POWER 150 TO 175%	A MEAN VALUE	150% POWER						175% POWER		2025 HRS	2050 HRS	2150 HKS			FINAL DATA	MIN VALUE	MAX VALUE	MEAN	STD DEV	

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											-													
	SUMMARY																							
	DATA SU																							
TABLE 5	- V3 I	N) 7.14(MAX)	A	MOT		6.532V 7.067V 6.820V	AND - 101				0.000V	7.000mV	6. 000mV	16.00mV	~	JOB STOPPED	→ →	 		225°C	6.535V	7.006V	6.803V 157.6mV	
• •	II TEMP	B _V =6.46V(MIN)	I _Z = 37.0mA	SIE		6. 533V 6. 830V 6. 652V	21555・16				-1.000mV	15.00mV	3.000тV	61.00mV *354.0mV	- - - -	JOB STOPPED	\rightarrow			225°C	6.673V	7.257V	7.006V	
•	GROUP	(MAX)		TOM		55.10nA 53.20µA 5.715µA	14.02µA				3.608µA	3.000µA 26.23µA	22.86µA	13.12µA *661.4µA	*4.989mA	JOB STOPPED	→ →			225°C	0.000mA	9.990mA	4.995mA	
		I _R = 150µA(MAX)	V _R = 5.2V	SIE		108.0nA 5.430µA 1.297µA	1. 398µA				250.0nA	284.0nA	130.0nA	266.0nA *717.1uA	196.4µA	JOB STOPPED	→ →			225°C	11.30nA	1.280mA	197.7µA	UN7.400
		PARAMETERS	CONDITIONS AND LIMITS .	IDENTIFICATION	INITIAL DATA	MIN VALUE MAX VALUE MEAN	STD DEV	INTERIM DATA (INITIAL TO FINAL)	Δ MEAN VALUE	TOTAL HRS TEMP (T _A)		320 100°C 480 125°C		800 175°C 960 202°C		1280 250 ⁰ C	1600 306 ^o C		FINAL DATA	FINAL TEMP	MIN VALUE	MAX VALUE		STD DEV

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

DGV Form 1800-1

				-													JANT	<u>K1N3</u>	01	6B			
							-															•	
	•								-														
ARY																							
DATA SUMMARY								-								 							-
TABLE 6 STRESS II	7.14(MAX)		MOT		6.533V 7.056V	6.815V 144.5mV					-6.000mV -5.000mV	-442.0mV	24.00mV	23.00mV -567.0mV				3000	,	428.0mV 7 104V	6.248V	1.846V	s point
III TEMP	B _V =6.46V(MIN)	I _Z = 37.0mA	SIE		6.525V 6.792V	6.657V 97.44mV					-2.000mV	*4.613V	JOB STOPPED	*_ →					J. C77	6.761V	11.27V	14.86V	data aft er this
GROUP			MOT		12.80nA 3.750μA	552.1nA 873.2nA					14.26µA 28 11µA	1.254mA		788.0µA 843.5µA		 		30005		40.00pA	844.1µA	2.758mA	removed from da
	$I_{R} = 150 \mu A (MAX)$	V _R = 5.2V	SIE	-	108.0nA 13.00µA	1.530µА 3.092µА					-598.4nA	9.650µA	JOB STOPPED			 ·			۲-CZZ	21.00nA	5.531µA	6.192µA	reject(s) rem
	PARAMETERS	CONDITIONS AND LIMITS	IDENTIFICATION	INITIAL DATA	MIN VALUE MAX VALIIE	MEAN STD DEV	INTERIM DATA	(INITIAL TO FINAL)	A MEAN VALUE	TOTAL HRS TEMP (T _A)	16 150°C 150°C 32	200°C	250°C	96 275°C 112 300°C	· · · · ·		- 11	-	FINAL JEMP	MIN VALUE	MEAN	STD DEV	*NOTE. Catastrophic r

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						JAN	TX1N3016B
68		STRESS 11	MOTOROLA	*+560.88	*iĴúi		• • • •
JANTXIN3016B		TEMPERATURE	SIEMENS	+3.1409	*+2.3063		Jint
	IN MEAN VALUE	E STRESS I	MOTOROLA	*+817.12	00014		Catastrophic reject(s) removed from data after this point
	AVERAGE A 11	TEMPERATURE	SIEMENS	*+130.67	*+.11414		from data a
S 7 A SUMMARY		STRESS	MOTOROLA	*+90.313	+.01056		t(s) removed
TABLE 7 FINAL DATA SUMMARY		POWER S	1	*+181.24	*+.82344		rophic reje c
1		MEAN	DATA				Catasti
	>	z -	- +- v	Р МЦ	>		* NOTE:
	ATIONS	-	MAX	150	7.14		Ż *
	SPECIFICATIONS		Z		6.46		
		_1	PARAMETER	IR	'n		

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TAE	TABLE	8 8	STEP STR	RESS	CATASI	CATASTROPHIC		FAILUF	RE SUN	FAILURE SUMMARY			IAN H	JAN TXIN3016B	B
GROUP 1 POWER STRESS	POWER S	TRESS			GROUP 11	160 HR.	TEMP.	STEPS		GROUP III	16 HR.	TEMP.	STEPS		
TEST	MF	MFR A	MFR	88	TEST	MFR	K A	MFR	3 8	TEST	MFR	A R	MFR	8	
STEP	OTY.	NOTE	aty.	NOTE	STEP (TA)	ατγ.	NOTE	ατγ.	NOTE	STEP (TA)	ατγ.	NOTE	ΩTY.	NOTE	
50% 50 hr.	0	I	0	ı	75° C	0	1	0	1	150°C	0	·	0	·	
100 hr.	0	1	0	1	100° C	0	•	0	1	175°C	0	I	0	1	
100 hr.	0	•	0		125°C	0	1	0	ł	200 °C	3	ပ	7	۲ ۲	
250 hr.	0	1	0	ł	150°C	2	ပ	0	I	225 °C	13	ပ	1	۵	
100% 50 hr.	0	I	0	•	175°C	0	I	1	B	250°C	JOB S	TOPPED	0	1	
100 hr.	0	ı	υ	ł	200°C	1	A/C	$\overline{\langle}$	A C	275°C			-	1	
100 hr.	0	ł	0	I	225°C	6	ပ	<u> </u>	× A	300° C	>		7	U/m	
250 hr.	0	1	0	1	250°C	JOB ST	STOPPED	JQB S	TOPPEI	•					
125% 10 hr.	N.Y.	ACB	1	D	275°C					MFR		SIEMENS	NS		
15 hr.	JOB S'	STOPPED	0	1	300°C	->		->	->	MFR	"B"	MOTOROLA	OLA		
25 hr.			1	υ	NOTES.	۲ ۲	^	1 5mA							
100 hr.			0	1											
100 hr.			1	A		۱ 8	^B V < 3	3.23V							
250 hr.			0	1		l O	$B_{\rm V} > 1$	<pre>> 10.71V</pre>							
150% 10 hr.			0	1		ו נ	Shorte	d (ver	ified	Shorted (verified by failure analysis)	ure an	alvsis	~		
15 hr.			0	1							•				
25 hr.			0	1		। म्र	Open (Open (verified by	ed by	tailure analysis)	analy	sis)			
100 hr.			1	ပ											
100 hr.			0	•										×	
250 hr.			0	I											
175% 10 hr.			0	1			·								
15 hr.			0	1											
25 hr.			2	ш											
100 hr.			1	c											
100 hr.			1	A											•
250 hr .	->	->	JOB S	STOPPED											

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IABLE														
ROUP I	GROUP I POWER STRESS	TRESS			GROUP II		160 HR. TEMP.	STEPS		GROUP III		16 HR. TEMP.	STEPS	
TEST	MF	MFR A	MF	MFR B	TEST	MFR A	RA	MF	MFR B	TEST		۲ a	MFRB	
STEP	отγ.	NOTE	ΩTY.	NOTE	ξHe)	ατγ.	NOTE	ατγ.	NOTE	STEP (TA)	ату.	NOTE	QTY.	NOTE
50% 50 hr.	0	1	0	I	75° C	0		0	•	150 ° C	0	-	0	ł
100 hr.	0	1	0	1	100° C	0	1	0	1	175°C	0	1	2	A
100 hr.	0	,	0	1	125 °C	0	I	-	А	200 °C	Ž	A A	0	I
250 hr.	0	ł	0	I	150°C	0	1	0	1	225 °C	0	1	0	1
100% 50 hr.	0	1	0	1	175°C	1	В	0	1	250°C	JOB S'	COPPED	1	A
100 hr.	0	1	0	1	200°C	2	ß	0	i	275°C			1	ß
100 hr.	0	1	0	ł	225°C	0	1	0	1	300° C		>	0	1
250 hr.	0	1	1	¥	250°C	JOB ST	OPPED	JOB ST	OPPED					
125% 10 hr.	-	A&B	1	A	275°C					MFR	"A" -	SIEMENS	SN	
15 hr.	JOB S7	STOPPED	0	1	300 . C			\rightarrow		MFR	"B" -	MOTOROLA	DLA	
25 hr.			0	ł	AIOTEC.					_				
100 hr.			0	ı		I	\	VIIIC T •						
100 hr.			0	I		н В	B _V > 7	7.14V						
250 hr.			0	1		ו ט	B., < 6	6.46V						
150% 10 hr.			0	I			>							
15 hr.			0	ı										
25 hr.			0	1										
100 hr.			0	1										
100 hr.			1	А										
250 hr.			0	•										
175% 10 hr.			0	1										
15 hr.			0	I										
25 hr.			0	8										
100 hr.			7	B										
100 hr.			0	I										
250 hr.														

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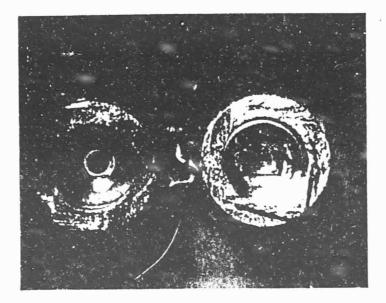
APPENDIX A

FAILURE ANALYSIS

POWER STRESS

ED		<u></u>		JAN	FX1N3016B .
Ø		FAIL	JRE ANALYSIS		. • •.
J/N_	2CN242-344.	P/N 1N30	16B MFF	Date 10 Nover	nber 1978
	Limits: 6.46-7.14V	Limit: <u>150µA Max</u> .			
s/n	PIV -volts- @ 37mA	I _R @ 5.2 V.dc	V _F @dc	INITIAL Rej. at test Sequence no.:	INITIAL REJ. FOR:
211 [:]	open arcs @ 200V	open		47 (175% power . 50 Hrs. Tot)	B _V
213	shorted	00		17 (100% power 500 Hrs. Tot)	I _R
215	open	open		47 (175% power 50 Hrs. Tot)	^B V
1					
/N 22 ntern /N 22 ONCLU 11 tl 215 f vire,	hal wire (see F 213 has no visu J <u>SIONS</u> hese Motorola s failed because thus disconnec	re open at the bo igure A-J). al defects. amples failed due the internal lead	to the thermal e bonding material N 2213 failed due	between the top of the d effects of excess power. I melted and flowed up the to shorting of the junc e.	S/N 2211 and e silver lead
	•				
* ^h FF	E trace prese E trace very		et stated test	conditions. (Leaky)	
D=d	lrift H=hyste	eresis Inv=inve	ersion R=resis	tive S=soft Uns=unsta	able

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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.



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APPENDIX B

FAILURE ANALYSIS

TEMPERATURE STRESS I

FAILURE ANTALYSIS

Date 10 November 1978

J/N.	2CN242-34B	P/N 1N3016E	MFR	MOTOROLA	
	Limits: 6.46-7.14V	Limit: 150 ^µ A			
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)	IR
2225	unstable; no reading*	unstable; no reading*		15 (225 ⁰ C 48 Hrs. Tot)	I _R
2229	open*	open*		13 (200 ⁰ C 960 Hrs. Tot)	^B v
	(*Die i	s 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).

*^hFE trace present. Cannot meet stated test conditions. (Leaky) **^hFE 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/N1N	N3016B	MFR	SIEMENS	
•	Limits: 6.46-7.14V	Limit: 150 ^µ A 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)	50µА, (D), (R) сарас. loop	,	_	13 (200 ⁰ C 960 Hrs. Tot)	^в v
2273	unstable no reading	unstable no reading			13 (200 ⁰ C 960 Hrs. Tot)	^B v
2274	R (Uns)	R (Uns)			15 (225 ⁰ 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).

*^hFE trace present. Cannot meet stated test conditions. (Leaky) **^hFE trace very leaky.

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



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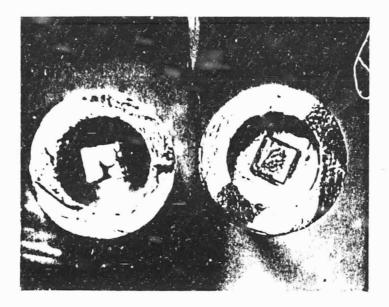


FIGURE B-1 S/N 2229, Internal View of Motorola Diode, 7X. Note loss of bonding material from the top of the die and the open die-to-wire connection.

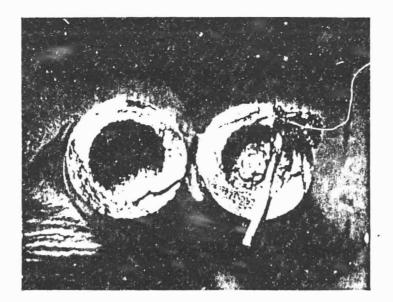


FIGURE B-2

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 silicor. 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

			RE AN (LYSIS Ture stress II)		
- 4	201242-240	n /m 11/30	160 MOB	Date 11 May	1978
J/N_	2CN242-34C	P/N 1N30	<u>168</u> MPR	MOTOROLA	
•	Limits: 6.46-7.14V	Limit: 150uA 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	150μΑ		03 (150 [°] C)	IR
2237	- ol	en -		13 (275 [°] C)	I _R
2237	6.8	0.2µAI	ternally probed		
2248	0.5(R)	can't reach(R)		11 (250 [°] C)	CAT
2248	sho	rtedI	ternally probed		
÷		:			
The s		n coating is somew		samples. S/N 2236 a igures C-l and C-2).	and 2237 have

è

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FAILURE ANALYSIS (TENEERATURE STRESS II)

Date 11 May 1978

J/N.	2CN242-34C	P/N	1N30	16B	_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	- 0	pen-				13 (275 [°] C)	CAT
2294	6.1	1.0µA		Internally	probed -		
2301	can't reach (R)	. 2mA				15(275 [°] C)	Ι _R 165μΑ
		:				:	

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).

*^hFE trace present. Cannot meet stated test conditions. (Leaky) **ⁿFE 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:

	<u>57 N</u>	FAILORE 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.

FATLURE MODE

S/N

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.

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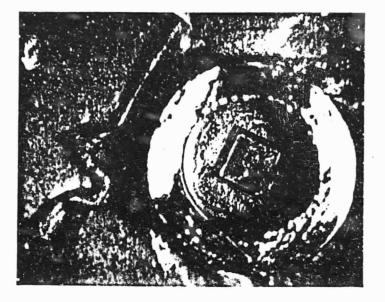


FIGURE C-1 S/N 2236, Top of Motorola Die Showing Detached Internal Anode Lead, 12X. Note the lead attach bonding material has

reflowed and is now on the S-bend of the lead.

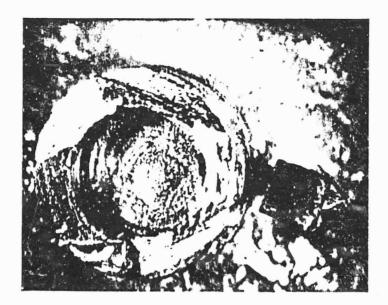


FIGURE C-2 S/N 2248, Motorola Device Showing Loss of Metallurgic Bond to Cathode, 12X. Cathode post shown on left; underside of die shown on right.



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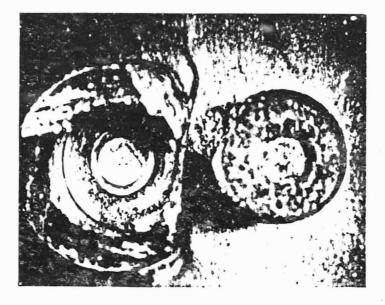
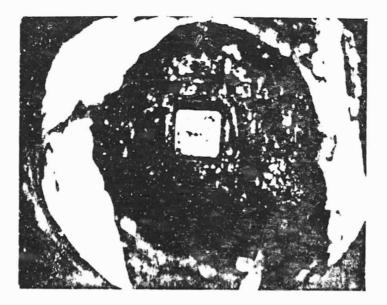


FIGURE C-3

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.



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