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TRANSISTOR

STEP STRESS TESTING PROGRAM

MSFC/NASA CONTRACT NUMBER
NAS8-31944

FINAL REPORT
FOR

JANTX 2N2905A

FEBRUARY 1979

Prepared
For

GEORGE C. MARSHALL SPACE FLIGHT CENTER
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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.

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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 transistor JANTX2N2905A manufactured by Texas Instruments 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 of the test devices during the power/temperature stress conditions. The current was set by I_E and the voltage was varied in order to comply with the specified power rating for this 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 Texas Instruments. The Texas Instruments sample lot completed a total of 1750 hours of Group I Testing before the lot was stopped because of an excessive amount of mechanical failures due to handling. Serial number 4708 was listed as a handling failure 150 hours into the 125% MRP step. Serial numbers 4703 and 4713 were listed as handling failures 250 hours into the 125% MRP step. Serial number 4705 was listed as a handling failure 10 hours into the 150% MRP step. Serial numbers 4711 and 4714 were listed as handling failures 25 hours into the 150% MRP step. Serial number 4706 was listed as a handling failure 50 hours into the 150% MRP step. Serial number 4712 was listed as missing from the Group I Testing 250 hours into the 50% MRP step. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 32.96pA from an initial mean of 21.33pA to a final mean of 54.29pA.

2) The mean value for h_{FE} changed 4.1 from an initial mean of 169.5 to a final mean of 165.4.

3) The mean value for $V_{CE(SAT)1}$ changed 1.0mV from an initial mean of 168.6mV to a final mean of 167.6mV.

4) The mean value for $V_{CE(SAT)2}$ changed 2.5mV from an initial mean of 466.4mV to a final mean of 468.9mV.

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

3.1.2 Motorola. The Motorola sample lot completed the entire 2500 hours of Group I Testing with a total of three catastrophic failures. The first two catastrophic failures occurred 500 hours into the 125% MRP step. Serial number 4765 failed the maximum $V_{CE(SAT)}$ limit. Serial number 4767 failed the maximum I_{CBO} limit. The last catastrophic failure occurred 50 hours into the 150% MRP step. Serial number 4769 failed because of an open emitter (see Failure Analysis, Appendix "A"). Serial numbers 4756, 4766, 4763, 4755 and 4770 were removed from the Group I Testing as visual failures due to handling. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 383.9pA from an initial mean of 705.9pA to a final mean of 322.0pA.
2) The mean value for h_{FE} changed 25.5 from an initial mean of 117.8 to a final mean of 143.3.
3) The mean value for $V_{CE(SAT)1}$ changed 992.1mV from an initial mean of 175.9mV to a final mean of 1.168V.
4) The mean value for $V_{CE(SAT)2}$ changed 995.1mV from an initial mean of 527.9mV to a final mean of 1.523V.

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 Texas Instruments and Motorola.

3.2 Group II - Temperature Stress I

3.2.1 Texas Instruments. The Texas Instruments sample lot completed a total of 1280 hours of Group II Testing before the lot was stopped because more than 50% of the lot had failed. The first six failures occurred 160 hours into the 225°C-temperature step. Serial numbers 4721, 4722, 4724, 4727, 4732 and 4734 failed the maximum I_{CBO} limit. The last five failures occurred 160 hours into the 250°C-temperature step. Serial numbers 4723, 4725, 4730, 4735 and 4736 failed the maximum I_{CBO} limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 499.4nA from an initial mean of 376.9pA to a final mean of 499.8nA.
2) The mean value for h_{FE} changed 319.7 from an initial mean of 178.9 to a final mean of 498.6.
3) The mean value for $V_{CE(SAT)1}$ changed 13.1mV from an initial mean of 172.1mV to a final mean of 185.2mV.
4) The mean value for $V_{CE(SAT)2}$ changed 91.0mV from an initial mean of 487.0mV to a final mean of 578.0mV.

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

3.2.2 Motorola. The Motorola sample lot completed the entire 1600 hours of Group II Testing with a total of two catastrophic failures. The first catastrophic failure occurred 160 hours into the 225°C-temperature step. Serial number 4772 failed the minimum h_{FE} limit. The last failure occurred 160 hours into the 275°C-temperature step. Serial number 4784 failed the maximum I_{CBO} limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 33.12nA from an initial mean of 1.04nA to a final mean of 34.16nA.
2) The mean value for h_{FE} changed 14.4 from an initial mean of 134.4 to a final mean of 148.8.
3) The mean value for $V_{CE(SAT)1}$ changed 36.2mV from an initial mean of 186.0mV to a final mean of 149.8mV.
4) The mean value for $V_{CE(SAT)2}$ changed 89.1mV from an initial mean of 586.2mV to a final mean of 497.1mV.

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 Texas Instruments and Motorola.

3.3 Group III - Temperature Stress II

3.3.1 Texas Instruments. The Texas Instruments sample lot completed a total of 96 hours of Group III Testing before the lot was stopped because more than 50% of the devices failed. The first failure occurred 16 hours into the 225°C-temperature step.

Serial number 4745 failed the minimum h_{FE} limit. The last eight failures occurred 16 hours into the 275°C-temperature step. Serial numbers 4739, 4741, 4743, 4744, 4746, 4747, 4748 and 4752 failed the maximum I_{CBO} limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 532.6 nA from an initial mean of 608.1pA to a final mean of 533.2nA.
2) The mean value for h_{FE} changed 144.7 from an initial mean of 180.3 to a final mean of 325.0.
3) The mean value for $V_{CE(SAT)1}$ changed 1.7mV from an initial mean of 159.3mV to a final mean of 157.6mV.
4) The mean value for $V_{CE(SAT)2}$ changed 21.3mV from an initial mean of 454.8mV to a final mean of 476.1mV.

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 no catastrophic failure. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 0.296nA from an initial mean of 1.651nA to a final mean of 1.355nA.
2) The mean value for h_{FE} changed 16.1 from an initial mean of 127.7 to a final mean of 143.8.
3) The mean value for $V_{CE(SAT)1}$ changed 34.6mV from an initial mean of 194.4mV to a final mean of 159.8mV.

4) The mean value for $V_{CE(SAT)2}$ changed 1.5mV from an initial mean of 591.3mV to a final mean of 589.8mV.

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 Texas Instruments 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

In summary, we find that 13 parts were destroyed by handling and 25 other parts failed catastrophically for various reasons. Many of the devices, from both manufacturers, failed due to thermal overstress which caused gold/aluminum intermetallics to form, and which degraded the collector-base junctions. The excess die temperature and intermetallic attack upon the oxide allowed metallic impurities to contaminate the oxide and thus degrade the transistor characteristics.

A plot showing cumulative failure distribution for Groups II and III was drawn for the Texas Instruments sample lot (Figures 2 and 3), but a complete plot for the Motorola sample lot could not be drawn due to an absence of failures in the Group III Testing. Figures 2 and 3 display the data for the Texas Instruments sample lot used to calculate an activation energy of 2.38eV.

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.

The activation energy was calculated from the formula:

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

Where: tt_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 ^{o}C of 16% failure for Group II.

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

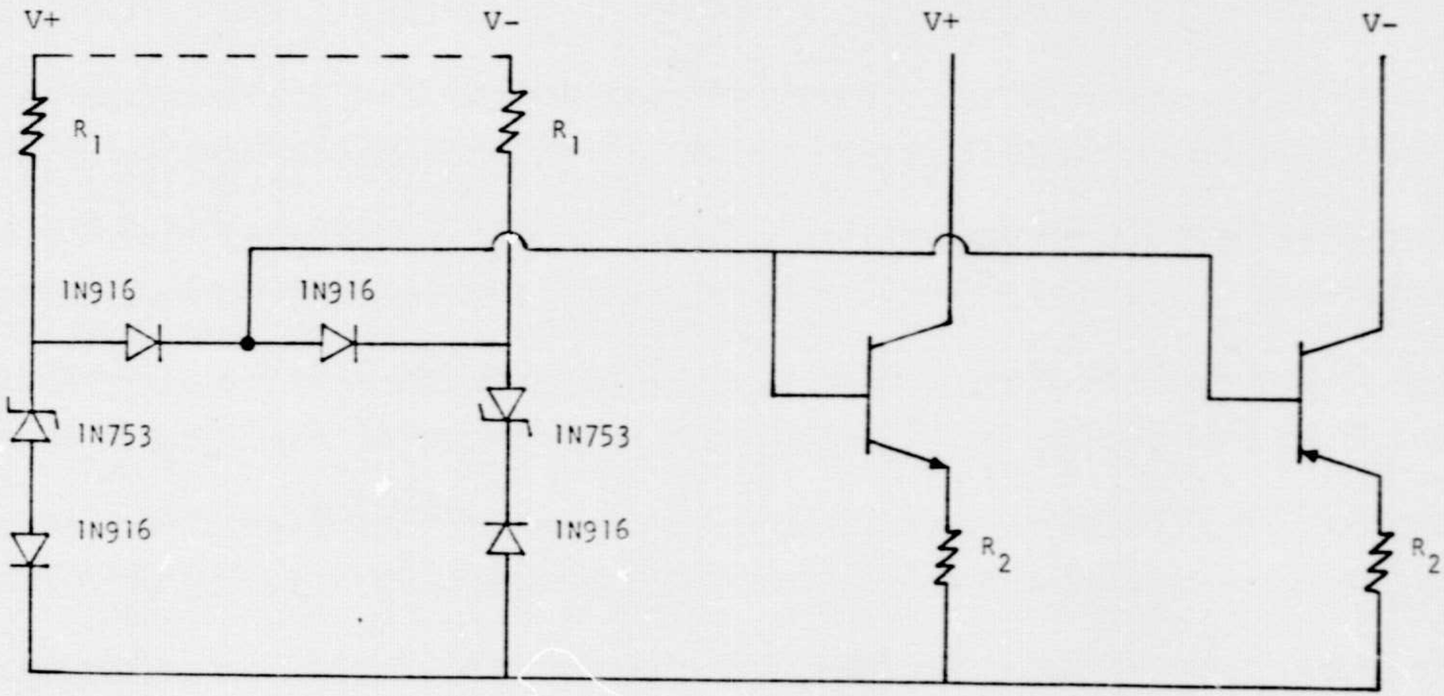
NOTE:

* 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.



NOTES: R_1 = 800±5%, 2W. R_2 = 150Ω, ±1%, 1/2W

Use V+ for NPN Transistors; Use V- for PNP Transistors.

FIGURE 1

Power/Temperature Stress Circuit

JANTX2N2905A

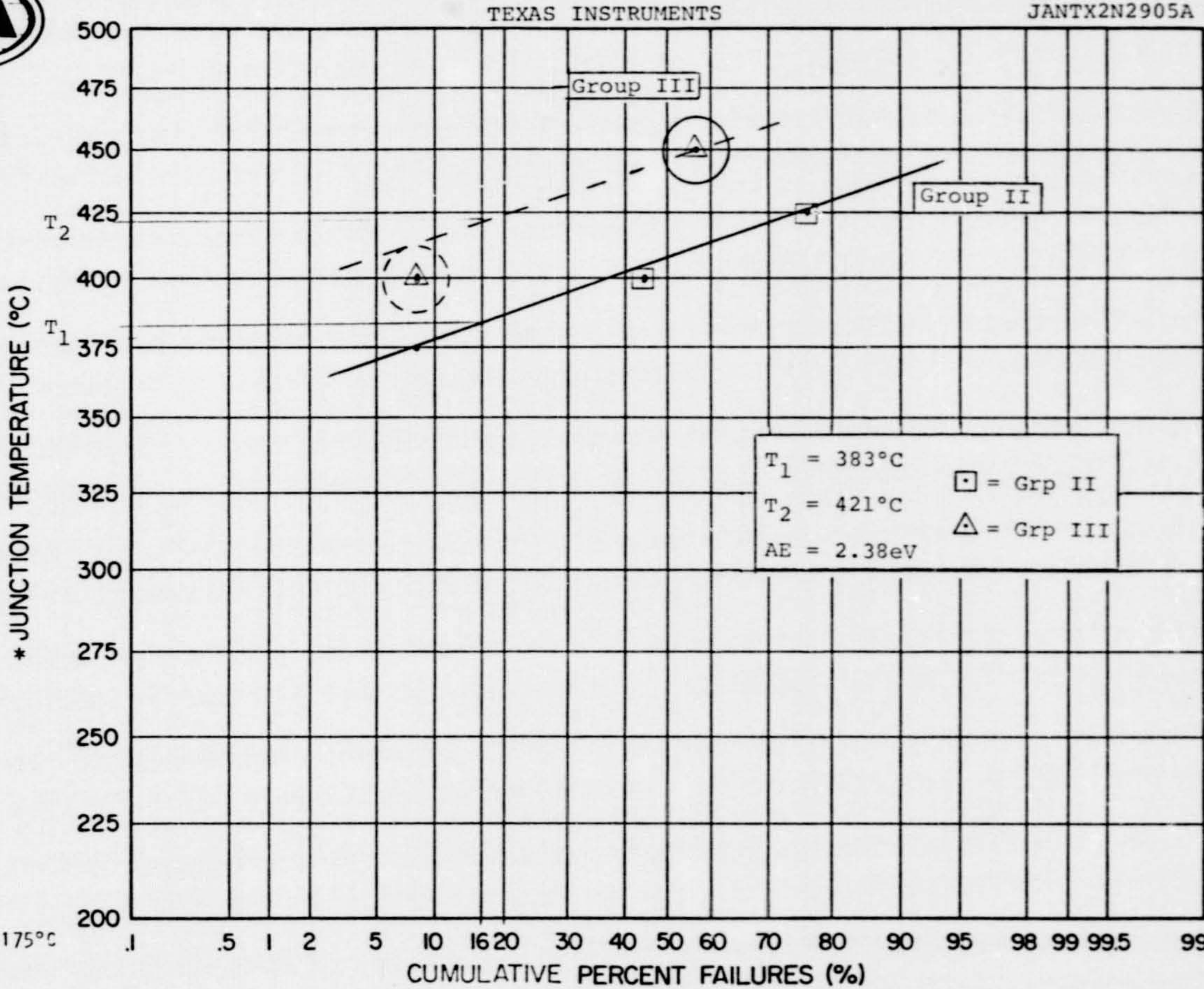
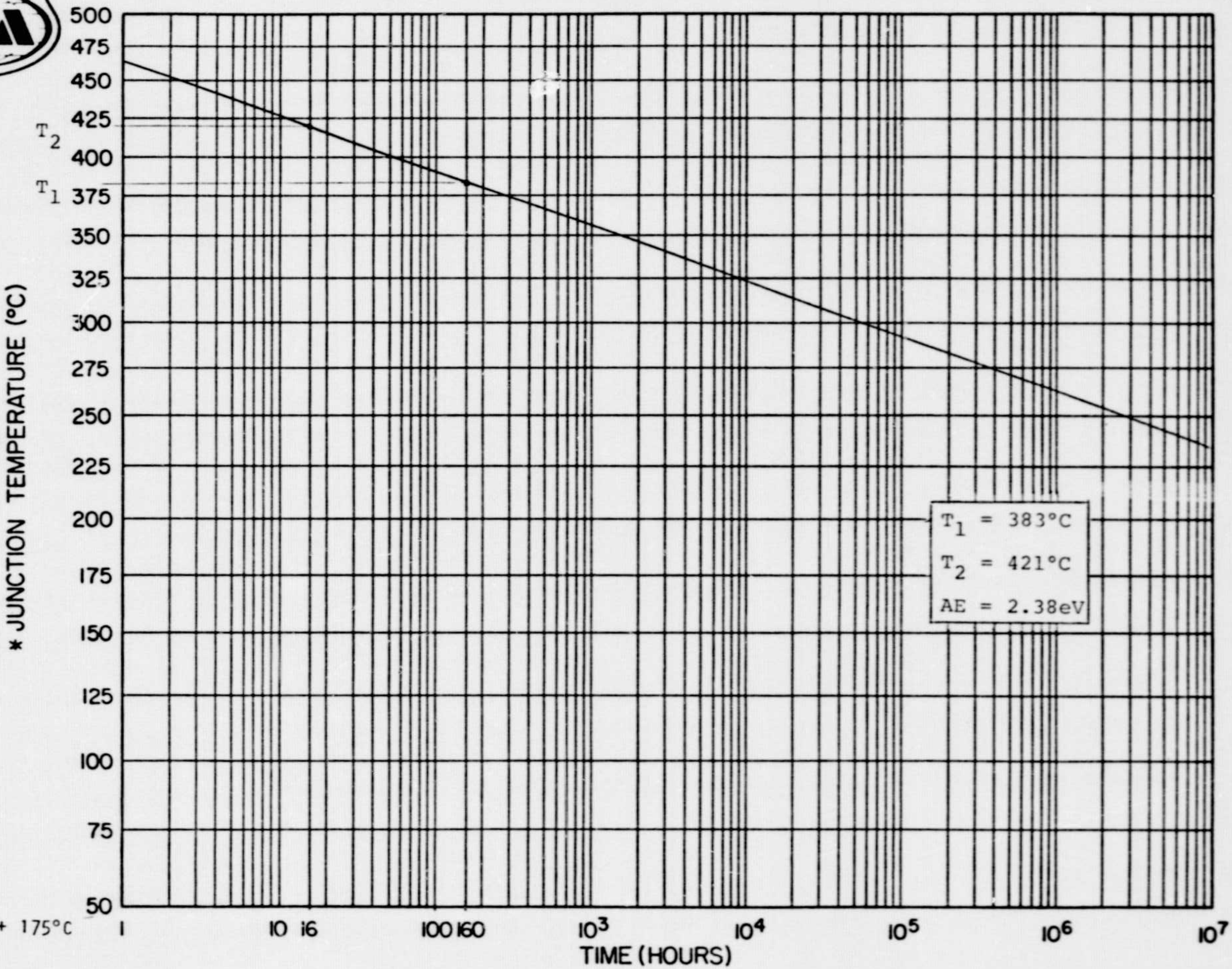


FIGURE 2

Cumulative Percent Failures Versus Junction Temperature, Texas Insturments

*NOTE

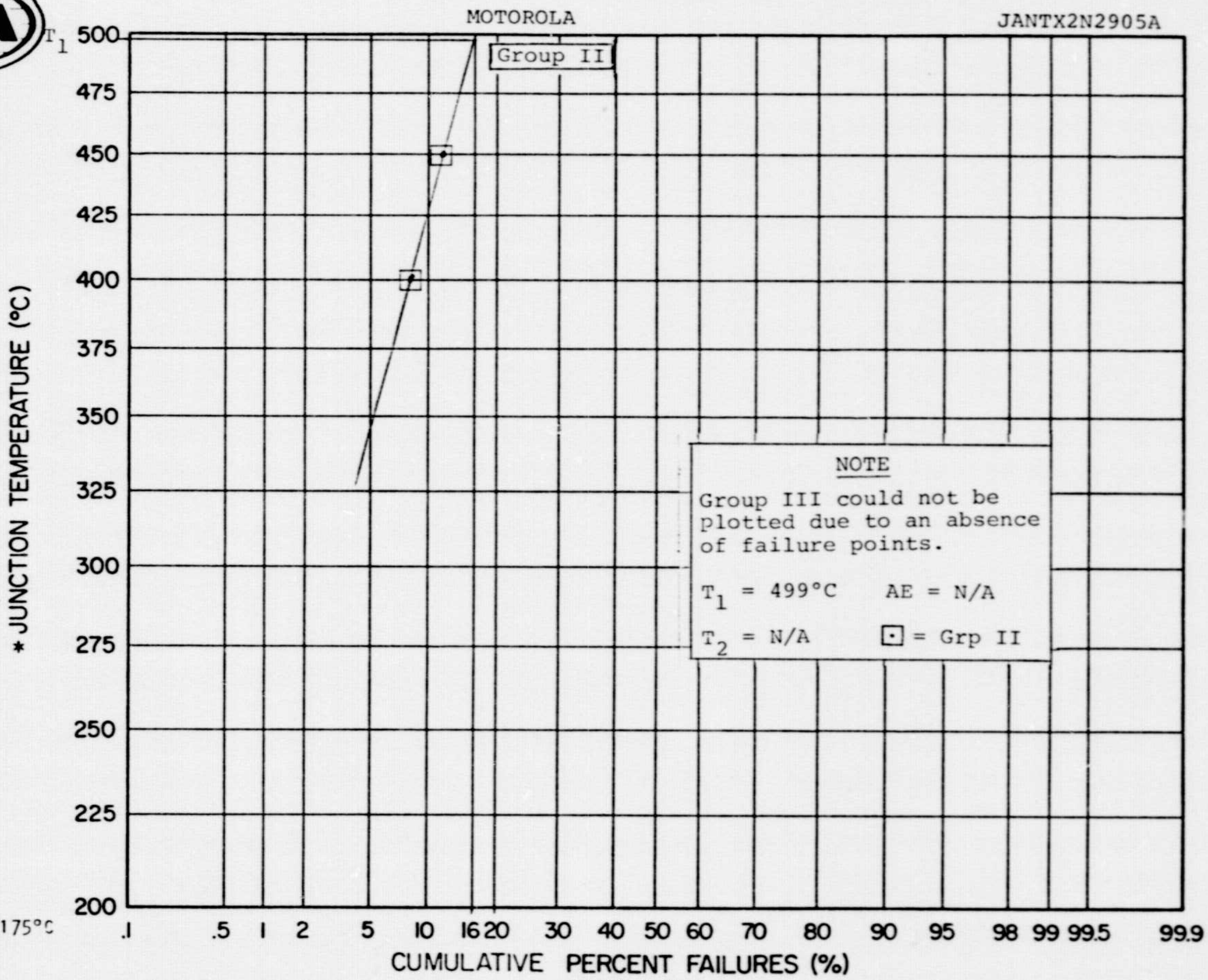
$T_J \approx T_A + 175°C$



*NOTE

$T_J \approx T_A + 175°C$

FIGURE 3
Time Steps Versus Junction Temperature, Texas Instruments



*NOTE

$T_J \approx T_A + 175°C$

FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, Motorola

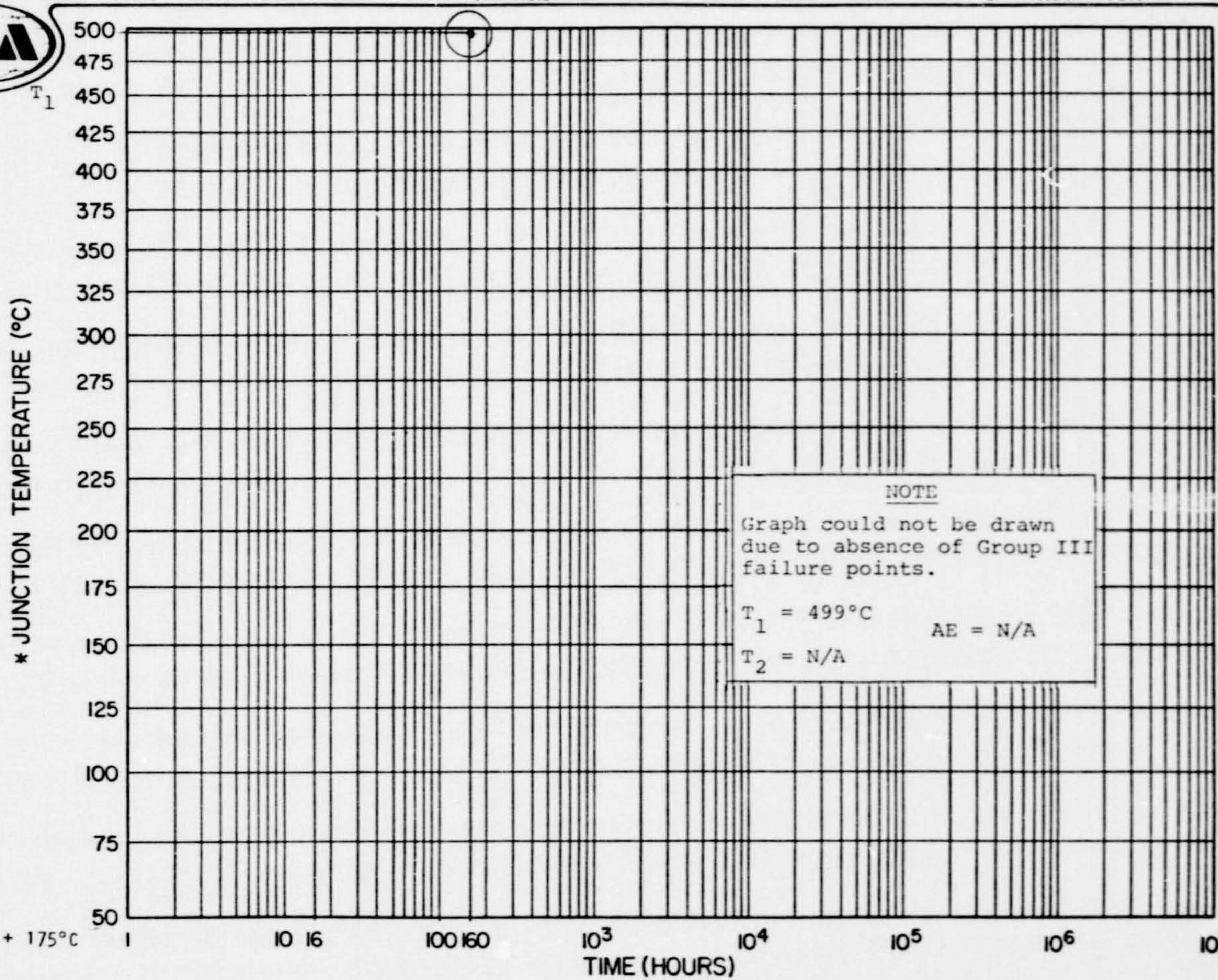
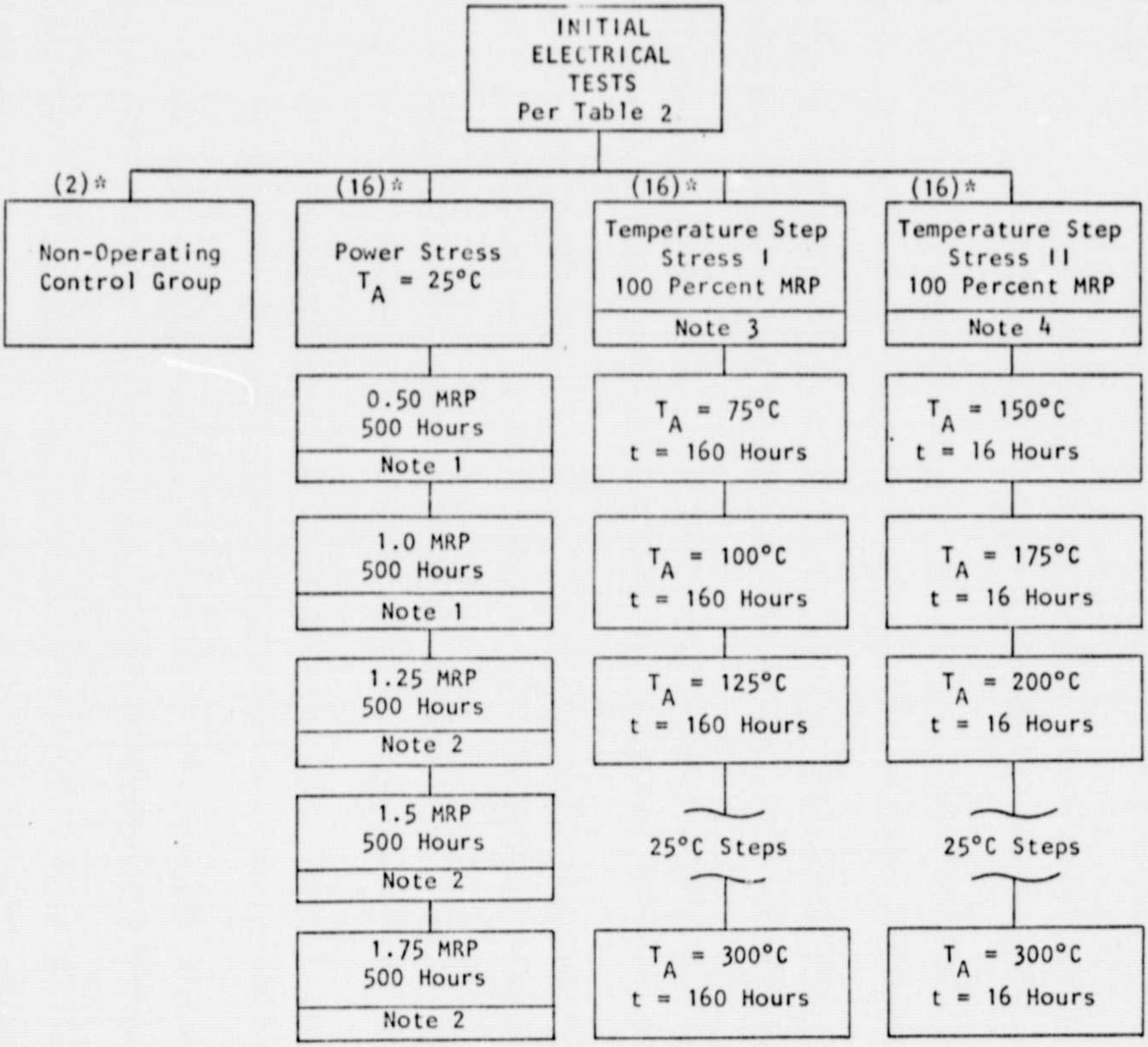


FIGURE 5
Time Steps Versus Junction Temperature, Motorola

*NOTE
J ≈ T_A + 175°C

TABLE 1
TEST FLOW DIAGRAM



*Quantity per manufacturer (Texas Instruments and 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_{CBO}	Per MIL-STD-750, Method 3036, Bias Condition D V_{CB} = -50Vdc	---	-10	---	-1000	nAdc
h_{FE}	V_{CE} = -10V dc I_C = -0.1mA dc	75	---	37.5	---	---
$V_{CE(SAT)}$	I_C = -150mA dc I_B = -15mA dc; Pulsed	---	-0.4	---	-0.6	Vdc
$V_{CE(SAT)}$	I_C = -500mA dc I_B = -50mA dc; Pulsed	---	-1.6	---	-2.4	Vdc

NOTES:

1/ In addition, any open or short shall be considered catastrophic

TABLE 3
POWER STRESS BURN-IN CONDITIONS

I_C = 12.0mA	
V_{CE}	Percent P_D
12.5	50
25.0	100
31.2	125
37.5	150
43.7	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_{CBO} = 10nA MAX.		h_{FE} = 75 MIN. V_{CE} = -10V dc		$V_{CE(SAT)1}$ = -0.4V(MAX)		$V_{CE(SAT)2}$ = -1.6V (MAX	
CONDITIONS AND LIMIT	V_{CB} = -50V dc		I_C = -0.1mA dc		I_B = -15mA		I_B = -50mA	
IDENTIFICATION	TI	MOT	TI	MOT	TI	MOT	TI	MOT
INITIAL DATA								
MIN VALUE	0.0 A	0.0 A	140	69.7	158 mV	0.00V	434.0mV	0.00V
MAX VALUE	260 pA	5.35nA	222	188.0	195 mV	255.0mV	520.0mV	797.0mV
MEAN	21.33pA	705.9pA	169.5	117.8	168.6 mV	175.9mV	466.4mV	527.9mV
STD DEV	65.00pA	1.249nA	20.58	33.89	9.258mV	56.96mV	20.75mV	184.2mV
INTERIM DATA								
POWER 50 TO 125% Δ MEAN VALUE								
50% POWER								
50 HRS	0 A	-20.0pA	0.4	0	-4.9mV	5.3mV	-23.4mV	8.0mV
150 HRS	0.67pA	68.2pA	2.6	0.5	9.9mV	11.9mV	21.4mV	43.9mV
250 HRS	8.67pA	-25.9pA	3.1	2.0	0.2mV	8.8mV	1.0mV	32.4mV
500 HRS	-3.47pA	-124.7pA	1.9	1.9	-0.1mV	8.7mV	0mV	31.7mV
100% POWER								
550 HRS	123.67pA	-139.4pA	2.5	6.9	0.5mV	11.6mV	2.7mV	32.2mV
650 HRS	-4.90pA	45.3pA	4.3	11.8	0.8mV	11.8mV	5.2mV	46.9mV
750 HRS	-1.33pA	-128.8pA	3.9	16.4	-0.7mV	8.6mV	-1.0mV	30.7mV
1000 HRS	5.81pA	-71.8pA	4.1	12.9	0.1mV	9.2mV	1.8mV	34.6mV
125% POWER								
1010 HRS	6.53pA	-38.3pA	5.1	16.7	14.1mV	13.0mV	20 mV	45.7mV
1025 HRS	3.67pA	-123.0pA	4.9	17.2	-0.7mV	8.1mV	-1.7mV	30.3mV
1050 HRS	-4.19pA	-200.3pA	4.4	16.5	-0.6mV	8.9mV	-1.2mV	32.5mV
1150 HRS	17.24pA	-269.4pA	8.3	20.2	-0.1mV	8.1mV	0.1mV	30.5mV
1250 HRS	27.76pA	-200.0pA	-1.1	17.1	2.7mV	13.2mV	9.1mV	54.3mV
1500 HRS	0.49pA	-388.8pA*	1.2	34.7	-0.1mV	4.3mV	1.0mV	*39.5mV

(continued on second sheet)

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TABLE 4 (Cont'd)

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

PARAMETER	I_{CBO} = 10nA MAX		h_{FE} = 75 MIN V_{CE} = -10mA		$V_{CE(SAT)1}$ = -0.4V MAX V_{CE} = -150mA		$V_{CE(SAT)2}$ = -1.6V MAX I_C = -500mA	
CONDITIONS AND LIMITS	V_{CB} = 50V dc		I_C = -0.1mA dc		I_B = -15mA		I_B = -50mA	
IDENTIFICATION	TI	MOT	TI	MOT	TI	MOT	TI	MOT
INITIAL DATA								
MIN VALUE	0.0 A	0.0 A	140.0	69.7	158.0mV	0.00V	434.0mV	0.00V
MAX VALUE	260 pA	5.35nA	222.0	188.0	195.0mV	255.0mV	520.0mV	797.0mV
MEAN	21.33pA	705.9pA	169.5	117.8	168.6mV	175.9mV	466.4mV	527.9mV
STD DEV	65.0pA	1.249nA	20.58	33.89	9.258mV	56.96mV	20.75mV	184.2mV
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 HRS	13.22pA	-474.5pA	3.6	38.6	0.1mV	2.7mV	1.1mV	35.6 mV
1525 HRS	9.67pA	-411.6pA	-2.2	34.9	-2.1mV	6.0mV	-0.1mV	45.5 mV
1550 HRS	18.67pA	-357.4pA	-3.1	*31.13	-1.9mV	*709.4mV	-0.4mV	*730.1 mV
1650 HRS	21.53pA	-485.9pA	-3.9	35.9	-3.3mV	7.1mV	-3.5mV	38.9 mV
1750 HRS	32.96pA	-448.4pA	-4.1	38.6	-1.0mV	8.4mV	2.5mV	43.7 mV
2000 HRS - Note 1	JOB STOPPED	-383.9pA	JOB STOPPED	38.5	JOB STOPPED	9.1mV	JOB STOPPED	46.5 mV
175% POWER								
2010 HRS	↓	-454.2pA	↓	39.8	↓	5.6 mV	↓	35.6 mV
2025 HRS	↓	-478.4pA	↓	38.5	↓	7.0 mV	↓	40.1 mV
2050 HRS	↓	-369.1pA	↓	40.0	↓	6.6 mV	↓	39.7 mV
2150 HRS	↓	-449.2pA	↓	39.8	↓	2.2 mV	↓	27.6 mV
2250 HRS	↓	-417.9pA	↓	41.8	↓	10.5 mV	↓	46.6 mV
2500 HRS	↓	-383.9pA	↓	25.5	↓	992.1 mV	↓	995.1 mV
FINAL DATA/HOURS	1750	2500	1750	2500	1750	2500	1750	2500
MIN VALUE	0.0 A	10.00pA	146.0	0	159.0mV	148.0mV	450.0mV	424.0mV
MAX VALUE	380.0pA	1.340nA	186.0	224.0	177.0mV	9.99V	488.0mV	9.99V
MEAN	54.29pA	322.0pA	165.4	143.3	167.6mV	1.168V	468.9mV	1.523V
STD DEV	133.0pA	384.0pA	13.36	56.58	5.123mV	2.941V	11.58mV	2.825V

NOTE 1: Test stopped due to excessive meachnical failures due to handling.

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

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TABLE 5

GROUP II TEMP STRESS I DATA SUMMARY

PARAMETERS	I_{CBO} = 10nA MAX		h_{FE} = -75 MIN		$V_{CE(SAT)1}$ = -0.4V MAX		$V_{CE(SAT)2}$ = -1.6V MAX	
CONDITIONS AND LIMITS	V_{CB} = -50V dc		V_{CE} = -10V dc, I_C = -0.1mA dc		I_C = -150mA, I_B = -15mA		I_C = -500mA, I_B = -50mA	
IDENTIFICATION	TI	MOT	TI	MOT	TI	MOT	TI	MOT
INITIAL DATA								
MIN VALUE	340.0pA	380.0pA	99.0	83.7	159.0mV	140.0mV	442.0mV	387.0mV
MAX VALUE	430.0pA	2.54nA	237.0	184.0	194.0mV	246.0mV	554.0mV	1430mV
MEAN	376.9pA	1.044nA	178.9	134.4	172.1mV	186.0mV	487.0mV	586.2mV
STD DEV	27.55pA	710pA	31.61	28.26	8.54mV	30.14mV	26.07mV	238.0mV
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE — TOTAL HRS / TEMP (T_A)								
160 / 75°C	128.7pA	68 pA	-2.2	21.3	-2.4mV	-3.1mV	-2.4mV	-1.3mV
320 / 100°C	141.9pA	53 pA	-0.8	20.5	-2.0mV	-2.8mV	-1.3mV	-0.9mV
480 / 125°C	265.0pA	93 pA	-1.4	21.5	-2.8mV	-3.2mV	-2.9mV	-2.4mV
640 / 150°C	166.8pA	170 pA	-1.3	27.2	-4.8mV	-3.1mV	0.2mV	3.8mV
800 / 175°C	121.8pA	7 pA	-7.0	28.9	-4.3mV	-3.1mV	8.1mV	11.4mV
960 / 200°C	261.3nA	77.1pA	-11.7	29.7	-5.7mV	-9.9mV	15.3mV	7.1mV
1120 / 225°C	*297.8µA	-115.3pA	-304.5	*16.2	6.2mV	-16.5mV	60.3mV	7.6mV
1280 / 250°C	*499.4nA	-67.8pA	-319.7*	13.8	13.1mV	-24.1mV	91.0mV	17.5mV
1440 / 275°C	JOB STOPPED	*69.88nA	JOE STOPPED	10.1	JOB STOPPED	-34.9mV	JOB STOPPED	625.8mV
1600 / 300°C	↓ ↓	33.12nA	↓ ↓	14.4	↓ ↓	-36.2mV	↓ ↓	-89.1mV
FINAL DATA								
FINAL TEMP (T_A)	250°C	300°C	250°C	300°C	250°C	300°C	250°C	300°C
MIN VALUE	480 pA	520 pA	143	98	156mV	128mV	460mV	384mV
MAX VALUE	999 nA	431 nA	999	199	346mV	174mV	1040mV	727mV
MEAN	499.8nA	34.16nA	498.6	148.8	185.2mV	149.8mV	578mV	497.1mV
STD DEV	499.2nA	114.6nA	408.7	28.96	54mV	15.11mV	170mV	98.6mV

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

TABLE 6

GROUP III TEMP STRESS II DATA SUMMARY

PARAMETERS	I_{CBO} = 10nA Max.		h_{FE} = 75 Min.		$V_{CE(SAT)1}$ = -0.4V Max.		$V_{CE(SAT)2}$ = -1.6V Max.	
CONDITIONS AND LIMITS	V_{CB} = -50V dc		V_{CE} = -10V dc I_C = -0.1mA dc		I_C = -150mA I_B = -15mA		I_C = -500mA I_C = -50mA	
IDENTIFICATION	TI	MOT	TI	MOT	TI	MOT	TI	MOT
INITIAL DATA								
MIN VALUE	360 pA	180 pA	159.0	71.0	143.0mV	148.0mV	402 mV	398.0mV
MAX VALUE	4.17nA	6.32nA	233.0	164.0	177.0mV	275.0mV	506 mV	787.0mV
MEAN	608.1pA	1.651nA	180.3	127.7	159.3mV	194.4mV	454.8mV	591.3mV
STD DEV	919.7pA	1.757nA	18.7	27.42	20.56mV	29.26mV	35.0mV	92.7mV
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS / TEMP (T_A)								
16 / 150°C	-90 pA	.046nA	0.5	4.6	-2.4mV	-4.1mV	9.1mV	-3.2mV
32 / 175°C	-20.6pA	.045nA	-1.4	10.9	-1.7mV	-5.5mV	6.5mV	-4.4mV
48 / 200°C	88.8pA	-.267nA	-10.0	14.9	-2.3mV	-4.4mV	11.4mV	-24.5mV
64 / 225°C	62.34pA	-.249nA	*-16.7	20.9	-2.8mV	-10.6mV	13.3mV	-20.6mV
80 / 250°C	528.9pA	-.180nA	-22.8	23.8	-4.3mV	-18.3mV	4.3mV	-19.6mV
96 / 275°C	*532.5nA	-.169nA	*144.7	21.5	-1.7mV	-31.9mV	21.3mV	-30.7mV
112 / 300°C	JOB STOPPED	-.296nA	JOB STOPPED	16.1	JOB STOPPED	-34.6mV	JOB STOPPED	-1.5mV
FINAL DATA								
FINAL TEMP	275°C	300°C	275°C	300°C	275°C	300°C	275°C	300°C
MIN VALUE	300 pA	320 pA	8.3	76.9	141.0mV	120.0mV	406.0mV	362.0mV
MAX VALUE	999 nA	5.64nA	999	198.0	184.0mV	190.0mV	617.0mV	793.0mV
MEAN	533.2nA	1.355nA	325.0	143.8	157.6mV	159.8mV	476.1mV	589.8mV
STD DEV	497.9nA	1.523nA	341.6	32.05	12.52mV	15.53mV	56.43mV	118.5mV

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

JANTX2N2905A

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			TI	MOT	TI	MOT	TI	MOT
I_{CBO}	---	-10	nA		+.0146	*-.2588	*+.2108	*+10.31	*+88.86	-.1500
h_{FE}	75	---	--		+1.89	*+23.76	*-81.0	*+20.36	*+15.72	+16.10
$V_{CE(SAT)}$	---	-0.4	V		+.0007	+.0730	-.0004	-.0137	-.0025	-.0156
$V_{CE(SAT)}$	---	-1.6	V		+.0018	*+.1007	+.0210	+.0580	+.0101	-.0149

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

TABLE 8 STEP STRESS CATASTROPHIC FAILURE SUMMARY JAN TX2N2905A

GROUP I POWER STRESS

TEST STEP	MFR A QTY.	MFR A NOTE	MFR B QTY.	MFR B 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.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	1 / 1	A / E
150% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	1	D
100 hr.	0	-	0	-
100 hr.	JOB STOPPED*		0	-
250 hr.			0	-
175% 10 hr.			0	-
15 hr.			0	-
25 hr.			0	-
100 hr.			0	-
100 hr.			0	-
250 hr.			0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A QTY.	MFR A NOTE	MFR B QTY.	MFR B NOTE
75° C	0	-	0	-
100° C	0	-	0	-
125°C	0	-	0	-
150°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	6	A	1	C
250°C	5	A	0	-
275°C	JOB STOPPED		1	A
300°C			0	-

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A QTY.	MFR A NOTE	MFR B QTY.	MFR B NOTE
150°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	1	C	0	-
250°C	0	-	0	-
275°C	8	A	0	-
300°C	JOB STOPPED		0	-

MFR "A" - TEXAS INSTRUMENTS

MFR "B" - MOTOROLA

NOTES:

A - $I_{CBO} \geq 1000nA$

B - Test stopped due to excessive mechanical failures

C - $h_{FE} \leq 37.5$

D - Open

E - $V_{CE2} \geq 2.4V$

* See Note B above

TABLE 9 STEP STRESS PARAMETRIC FAILURE SUMMARY JAN TX2N2905A

GROUP I POWER STRESS

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

GROUP II 160 HR. TEMP. STEPS

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

GROUP III 16 HR. TEMP. STEPS

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

MFR "A" - TEXAS INSTRUMENTS

MFR "B" - MOTOROLA

NOTES:

A - Minimum h_{FE} failures

B - S/N 4712 missing

C - Lead(s) broken - electrically good

D - Maximum V_{CE2} failure

E - Maximum I_{CBO} failures

APPENDIX A

FAILURE ANALYSIS

POWER STEP STRESS

FAILURE ANALYSIS

Date 26 April 1978

J/N 2CN242-04A **P/N** 2N2905 (PNP) **MFR** TEXAS INSTRUMENTS

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -μA- @V_{CB} = 50 V.	BV_{EGO} -volts	h_{FE} @ I_C = 100μA; V_{CE}=10V	V_{BEO} -volts- @ I_{BEO}= 10 mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
4706	72	86	0.2nA	7.3	185	0.78	35 (150% Power, 50 Hrs.)	Catastrohpic-visual
4708	70S	100	0.2nA	7.3	122	0.76	25 (125% Power, 150 Hrs.)	Catastrophic-visual
4711	70	108	10.nA	7.6	172	0.78	33 (150% Power, 25 Hrs.)	Catastrophic-visual

INTERNAL VISUAL INSPECTION: S/N 4711 has some areas of non-significant abraded metallization under the glassivation (Figure A-1). The other 2 samples show no significant anomalies.

All rejected samples in this sublot have a missing external emitter lead. (Total of 8 including 2 control units.)

CONCLUSIONS: All the selected samples were functional and within acceptable limits. The only significant anomaly was the breaking off of the external wire leads. This breaking was caused by the use of close hole sockets on the burn-in boards. The leads had to be bent together for burn-in at each stage and then spread to normal separation for each test. These samples experienced from 25 to 35 cycles of bending and spreading before they broke. The main bending stress is concentrated where the leads exit from the glass of the header and all glass seals are somewhat cracked from this flexing (see Figure A-2).

Bend tests were performed on undamaged samples and on the remaining leads of the damaged samples and no evidence of crystallization or brittleness was found in 3 right angle bend cycles per wire.

Sample size - 8 ea.
Failure Analysis - 3 ea.

* 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

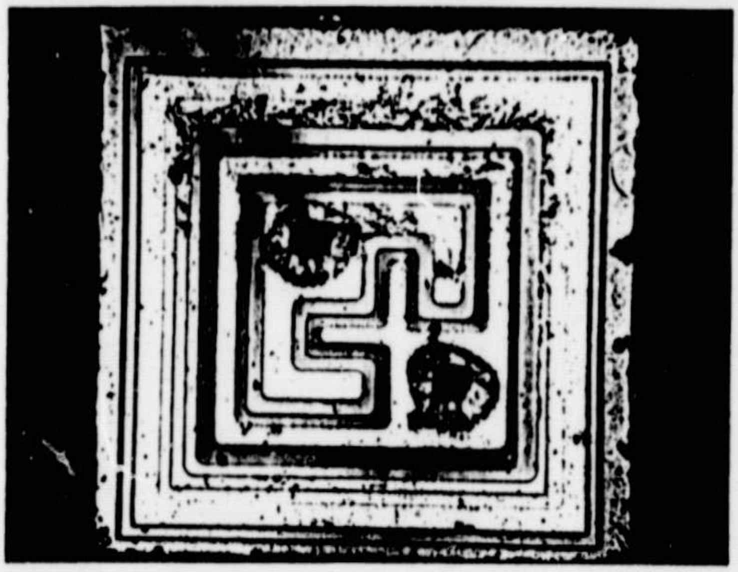

FIGURE A-1
S/N 4711, Texas Instruments Die Geometry, 144X.
(The dark areas in the metallization
are mechanically disturbed.)

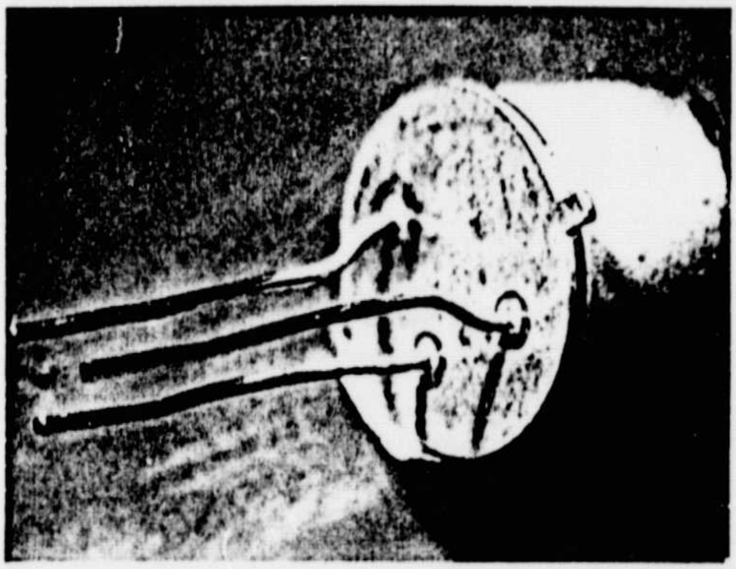

FIGURE A-2
S/N 4760, Magnification 5X.
Typical lead bending for
insertion in burn-in board.

FAILURE ANALYSIS

Date 26 April 1978

J/N 2CN242-04A P/N 2N2905 (PNP) MFR MOTOROLA

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	Max = 10 nA I_{CBO} -μA- @ V_{CB} = 50V.	BV_{EBO} -volts-	Min = 75 h_{FE} @ I_C = 100μA; V_{CE} = 10V.	V_{BEO} -volts0 @I_{BEO} = 10mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
4761	75	96	0.4nA	7.2	100	0.78	1-5 (50% Power, 150 Hrs.)	h_{FE}
4755	10→33[1]	90	0.4nA	7.0	159	0.75	(175% Power, 250 Hrs.)	Catastrophic - lead off
4769	open	short	∞	open	--	--	35 (150% Power, 50 Hrs.)	Catastrophic

INTERNAL VISUAL INSPECTION: S/N 4769 has been destroyed by electrical overstress (see Figure A-4).

The other two samples show nc significant internal anomalies.

S/N 4770 has a missing external emitter lead. This sublot contains nine devices with missing leads, including one control unit.

CONCLUSIONS: S/N 4769 was destroyed by high current operating over a long period of time. The emitter metallization and silicon were melted, as well as the internal gold emitter wire. (See Figure A-3.) The appearance of the damage suggests that the overstress current was greater than 2 amperes and flowed for longer than 100 microseconds. The voltage was not greater than the device breakdown of 30 to 75 volts. (S/N 4765 and 4767, which were not failure analyzed, also exhibited open emitters and are presumed to have the same failure mode as S/N 4769.) The source of the massive overstress is not known but the V_{SAT} tests suggest themselves as possibilities.

- Refer to Texas Instrument's analysis for a discussion of broken external leads.

Sample size - 9ea.
Failure Analysis - 3 ea.

1/ Initial breakdown occurs at 10 Volts and by increasing current, the second breakdown occurs at 33 Volts.

*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

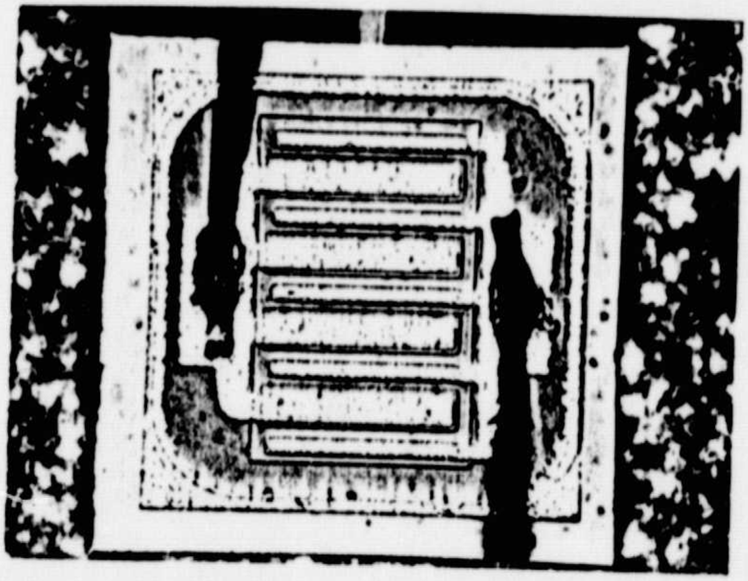

FIGURE A-3
S/N 4761, Typical Motorola Instruments
Die Geometry, 144X.

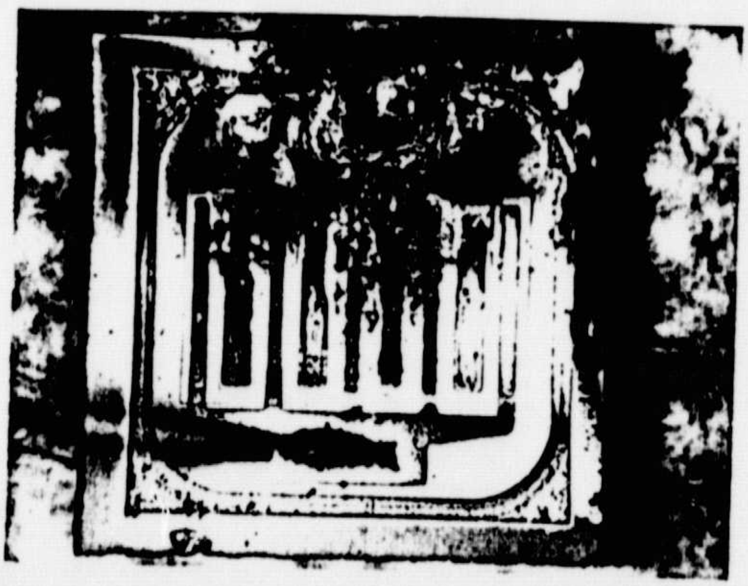

FIGURE A-4
S/N 4769, Motorola Device Destroyed
by Electrical Overstress, 144X.

APPENDIX B

FAILURE ANALYSIS

TEMPERATURE STRESS I

FAILURE ANALYSIS

Date 27 April 1978

J/N 2CN242-04B P/N 2N2905 (PNP) MFR TEXAS INSTRUMENTS

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -μA- @ V_{CB} = 50 V.	BV_{EBO} -volts-	h_{FE} @ I_C = 100μA; V_{CE} = 10 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
4722	0.58	4.8R	1.03mA	7.2	R	0.8	15 (100%, 160 Hrs. 225°C)	I_{CBO}, h_{FE}
4725	13.5	56S	5.0μA	7.2	54	0.79	17 (100%, 160 Hrs. 250°C)	I_{CBO}
4727	0.6	13.5R	600μA	7.3	R	0.78	15 (100%, 160 Hrs. 225°C)	I_{CBO}, h_{FE}

INTERNAL VISUAL INSPECTION

The appearance and conclusions for this subgroup are the same as for J/N 2CN242-04C (Texas Instruments).

Sample size - 3 ea.
Failure Analysis - 3 ea.

*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

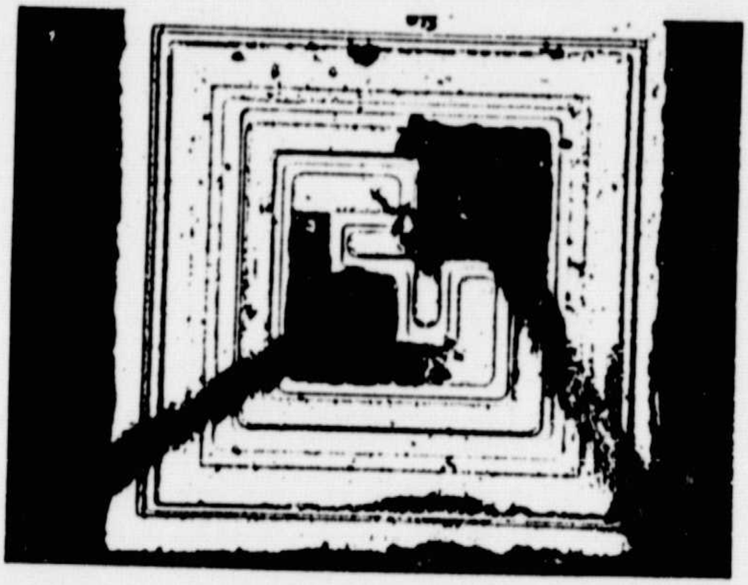

FIGURE B-1
S/N 4722, Typical Texas Instruments
Die Appearance, 160X.

FAILURE ANALYSIS

(TEMPERATURE STRESS II)

Date 28 April 1978

J/N 2CN242-04B **P/N** 2N2905 (PNP) **MFR** MOTOROLA

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -μA- @ V_{CB} = 50 V. (Max. 10 nA)	BV_{EBO} -volts-	@ I_C = 100μA; V_{CE} = 10 V. (Min. 75)	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
4772	50→80H	97	0.4nA	7.2	4.6	0.78	15 (100%, 160 Hrs. 225°C)	h_{FE}
4780	80H	92	0.4nA V_{BCO} @ 10mA = 0.75. $V_{CEO(SAT)}$ @ 150 mA = 0.35.	7.2	179	0.78	19 (100%, 160 Hrs. 250°C)	V_{CE}
4784	42→82H	104	0.5μA	7.1	158	0.76	19 (100%, 160 Hrs. 275°C)	I_{CBO}

INTERNAL VISUAL INSPECTION

S/N 4772 and 4780 have no significant visual defects.

S/N 4784 exhibits silicon damage on the base-collector junction (see Figure B-3).

*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

CONCLUSION

S/N 4772 This sample has lost most of its current gain without exhibiting any other junction anomalies sufficient to explain that loss. This suggests that the decreased h_{FE} was due to loss of emitter injection efficiency - specifically a loss of hole lifetime and/or mobility. Such a change could be induced by drifting of impurities under the influence of the high power and temperature used to stress the device. The change (increase) in collector-emitter breakdown voltages upon opening the packages and the hysteresis seen on those measurements is evidence that contamination was indeed present within the packages.

S/N 4780 This is a good unit. The V_{BEO} and V_{CBO} forward voltage data given above confirms that there is no abnormal resistance present in the contacts or package, and the $V_{CE(SAT)}$ at I_C = 150mA was within specified limits. This is considered to be a measuring error reject, possibly for poor contact, since the external leads of this sample are oxidized.

S/N 4787 There is a collector-base junction defect on this sample which breaks down at 70 volts. As the collector-base voltage is raised, a resistive trace appears on the curve tracer from 70 volts to the true breakdown at 104 volts. This defect is the cause of the excessive leakage for which the sample was rejected. See Figure B-3.

Sample Size = 3

Failure Analysis = 3

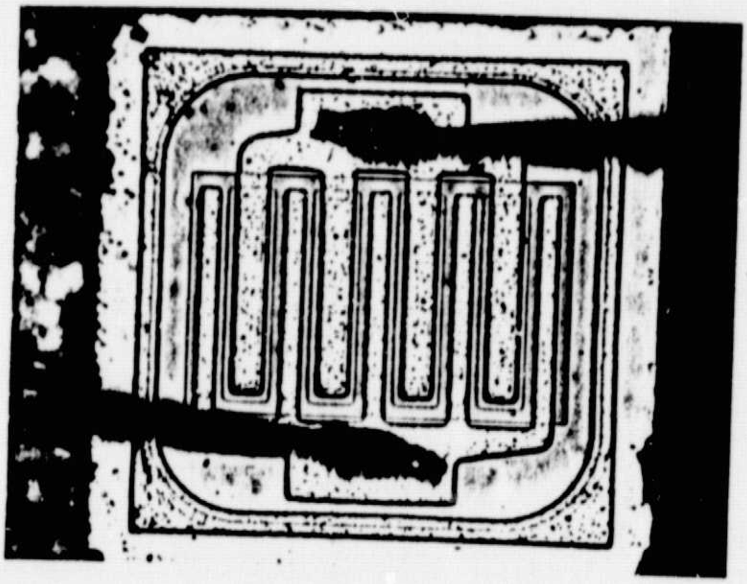

FIGURE B-2
S/N 4772, Typical Motorola
Die Geometry, 160X.

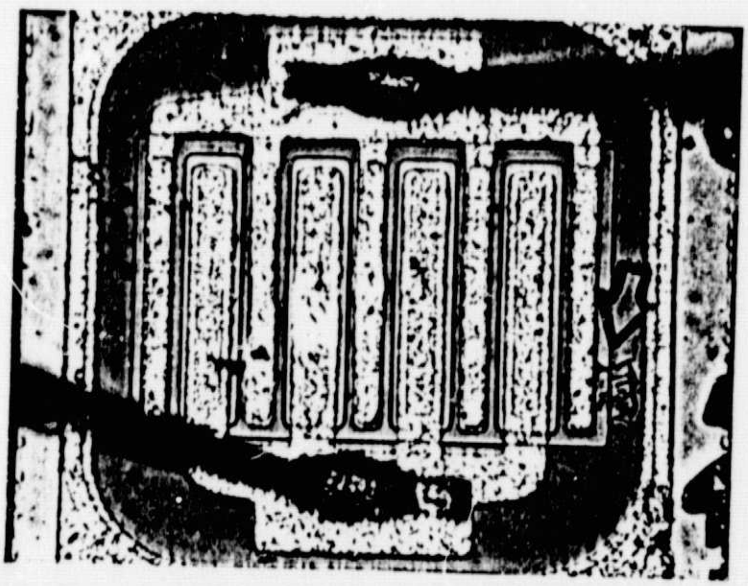

FIGURE B-3
S/N 4784, Motorola Sample, 200X.
Arrow indicates collector-base junction defect.

APPENDIX C

FAILURE ANALYSIS

TEMPERATURE STRESS II

JANTX2N2905A

FAILURE ANALYSIS

(TEMPERATURE STRESS II)

Date 20 March 1978

J/N 2CN242-04C **P/N** 2N2905A **MFR** TEXAS INSTRUMENTS

S/N	BV_{CEO} -volts- * See below	BV_{CBO} -volts- note below	I_{CBO} -µA- @ V_{CB} = 50 V. (Max. = 10 nA)	BV_{EBO} -volts-	h_{FE} I_B = 0.1µA; V_{CE} = 10V (Min. = 75)	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
E014737	35	100	<10nA	7.0	160	0.75	- not rejected -	
739	6.7S	15S	152.	7.2	25	0.70	11 (250°)	h_{FE}, I_{CBO}
745	80.uns	84uns	1.0	7.1	10	0.65	09 (225°)	Catastrophic
747	2.5S	16S	120.	7.2	*	0.68	11 (250°)	h_{FE}, I_{CBO}
752	1.8S	4.5	600.	7.4R	none	0.76	15 (300°)	Catastrophic

*NOTE: The BV_{CEO} and BV_{CBO} readings were measured at 5µA. Actual breakdown had not been reached on S/N 739, 747 and 752. The I_{CBO} readings were also below breakdown voltages.

INTERNAL VISUAL INSPECTION

All samples have severe intermetallic formation surrounding the base and emitter lead wires. No other significant defects were visable (see Figure C-1).

OTHER TESTS

Upon stripping the metallization and lead wires chemically, areas of damage to the surrounding oxide could be seen under the former intermetallics (see Figure C-2).

CONCLUSION

These samples failed due to thermal overstress which caused gold/aluminum intermetallics to form, and which degraded the collector-base junctions. The excess die temperature and intermetallic attack upon the oxide allowed metallic impurities to contaminate the oxide and thus degrade the transistor characteristics. The emitter-base junctions did not degrade because the higher boron concentration of the emitter diffusions gettered the impurities at the emitter-base junction. Sample size - 5 ea. Failure Analysis - 5 ea.

*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

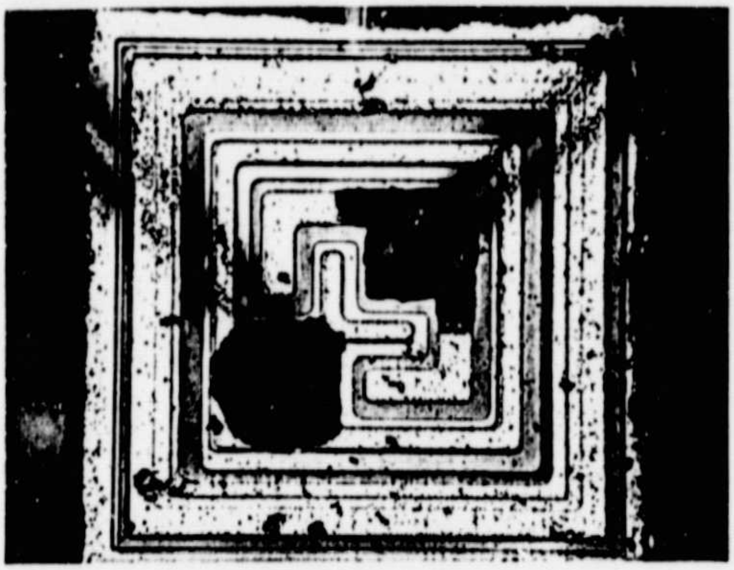

FIGURE C-1
S/N 739, Typical Overall Die View, 152X.
Dark areas of gold/aluminum
intermetallics surround the emitter
and base ball bonds.

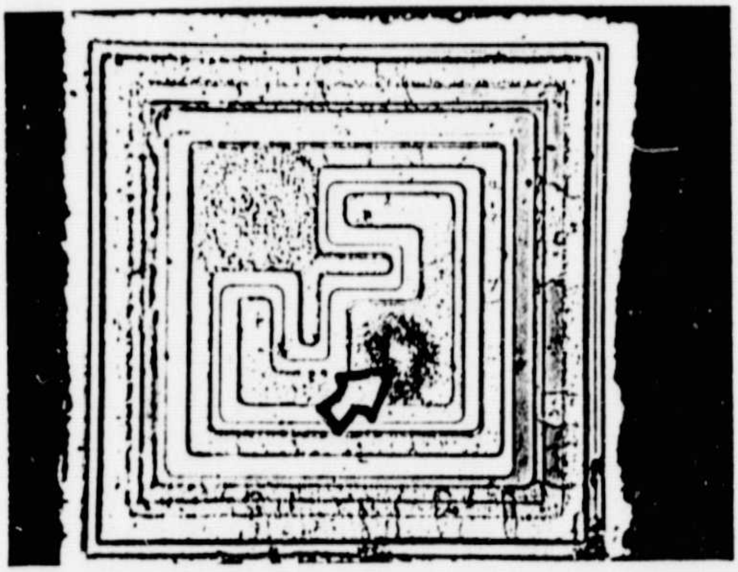

FIGURE C-2
S/N 739, Same Die as Figure C-1, 152X.
After stripping the metallization and wire bonds.
Arrow indicates damaged oxide which
was attacked by the intermetallics.