TRANSISTOR

STEP STRESS TESTING PROGRAM

MSFC/NASA CONTRACT NUMBER
NAS8-31944

FINAL REPORT
FOR

JANTX 2N2905A

REV A

Prepared
For

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

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F O R E W O R D

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.

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1.0 INTRODUCTION

This report is a summary of the work performed by DCA Reliability Laboratory, Sunnyvale, California, for NASA/MSFC, Huntsville, Alabama on Contract NAS8-31944 Transistor and Diode Stress Evaluation.

1.1 SCOPE

This program was executed to assess the effect of power and temperature stresses when applied to a variety of semiconductor devices. This report covers the transistor JANTX2N2905A, from Texas Instruments and Motorola.

1.2 SAMPLE DISTRIBUTION

A total of forty-eight samples from each manufacturer were divided equally (16 per group) among three groups and submitted to the processes outlined in Table I. In addition, two (2) control samples were maintained for verification of the electrical testing.

2.0 TEST REQUIREMENTS

2.1 ELECTRICAL

All test samples were subjected to the electrical tests outlined in Table II at each measurement point. These tests were carried out using the Fairchild Model 600C high-speed computer-controlled test system.

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2.2 STRESS CIRCUIT

The circuit in Figure 1 was used to power all of the test devices during the various stress conditions. The V_{CE} was adjusted to obtain the specified power requirements. See Table III, Page 9.

2.3 POWER STRESS

Thirty-two (32) units, Sixteen (16) from each manufacturer, were submitted to this process. The units were stressed for 500 hours at 50%, 100%, 150% and 175% maximum rated power (MRP). Electrical measurements were performed at various intervals. See Table I, Page 8.

2.4 TEMPERATURE STRESS I

Thirty-two (32) units, sixteen (16) from each manufacturer, were submitted to this process. This group was subjected to 1600 hours of stress at 100% MRP in increments of 160 hours with temperature steps of 25°C commencing at 75°C and terminating at 300°C. See Table I, Page 8.

2.5 TEMPERATURE STRESS II

Thirty-two (32) units, sixteen (16) from each manufacturer, were submitted to this process. This group was subjected to 112 hours of stress at 100% MRP in increments of 16 hours with temperature steps of 25°C commencing at 150°C and terminating at 300°C. See Table I, Page 8.

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3.0 DISCUSSION OF TEST RESULTS

3.1 POWER STRESS

3.1.1 TEXAS INSTRUMENTS

No rejects due to electrical failure were encountered until the test was terminated at 1750 hours. The electrical characteristics of this sample remained essentially constant throughout the entire test period. Typical of this performance, the mean value for h_{FE}, $V_{CE(SAT1)}$ and $V_{CE(SAT2)}$ changed less than 2.5%. I_{CBO} changed only 33pA from a mean of 21pA to a mean of 54pA. The test was terminated due to excessive mechanical failures induced by handling during the test program. See Appendix A, Page A-2.

3.3.2 MOTOROLA

This group started with two (2) parametric h_{FE} failures. These units continued to fail throughout the first 500 hours. After 50 hours at 100% MRP, both devices displayed enough increase in h_{FE} to meet the established parametric limit. This increase in h_{FE} was roughly paralleled by the good units. After 1500 hours, this group suffered two (2) catastrophic electrical failures, S/N 4765 and S/N 4767. Fifty (50) hours later, S/N 4769 also failed catastrophically. Failure analysis was performed on these units. See Appendix A, Page A-4. No other electrical failures were encountered with this group.

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3.1.3 STATISTICAL SUMMARY

Table IV outlines the results of the power stress for each parameter and measurement point for both vendors.

3.2 TEMPERATURE STRESS I

3.2.1 TEXAS INSTRUMENTS

This group progressed through all testing to 175°C with no failures or abnormal parametric changes. After 160 hours at 200°C, 960 hours into the test, two (2) units, S/N 4724 and S/N 4734 suffered a deterioration in I_{CBO}. S/N 4724 was catastrophic. At the end of an additional 160 hours at 225°C, five (5) more units showed a similar deterioration in I_{CBO}. All five of these units were catastrophic. Two of these units and one subsequent failure were subjected to failure analysis, with the only abnormality being that of severe intermetallic formations surrounding the base and emitter. See Appendix B, Page B-2. At the sixth sequence, 250°C, five (5) additional catastrophic failures ocurred. One (1) of these rejects was analyzed and found to be similar to previous failures. At this time testing was stopped due to excessive failures.

3.2.2 MOTOROLA

Until the post 225°C measurement, none of these units displayed any significant parametric changes. After the 225°C stress, one unit, S/N 4772, failed h_{FE}

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3.2.2 CONTINUED

catastrophically. This unit was submitted to failure analysis. See Appendix B, Page B-3. After the 250°C exposure, S/N 4780 drifted out of spec for V_{CE2}. This unit was marginal from the zero (Ø) hour measurement and this failure represents only a 240mV (17%) change. See Appendix B, Page B-3. An additional 160 hours at 275°C producted two (2) additional faiiures. S/N 4779 eventually became catastrophic and S/N 4784 continued to degrade and was subjected to failure analysis. See Appendix B, Page B-4.

3.2.3 STATISTICAL SUMMARY

Table V outlines the results of this temperature stress for each parameter, measurement point and vendor.

3.3 TEMPERATURE STRESS II

3.3.1 TEXAS INSTRUMENTS

After sixteen hours of exposures at 150°C, one unit, S/N 4737, displayed an 83% increase in I_{CBO}, as opposed to a mean change of approximately 10%. This condition persisted until after the 200°C cycle, at which time the reading more closely approximated the initial data. This reading continued stable until the test was terminated after the 275°C cycle. S/N 4737 was subjected to failure analysis. The only abnormality noted was the intermetallic

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3.3.1 CONTINUED

formations surrounding the base and emitter lead wires. See Appendix C, Page C-2. At the end of the 250°C stress, two (2) additional failures were encountered, S/N 4739 and S/N 4747. After failure analysis of these units, the internal characteristics were similar to S/N 4737, except they showed a distinct reduction in h_{FE} and an increase in I_{CBO}. See Appendix C, Page C-2. After the 250°C stress, S/N 4744 displayed a significant increase in I_{CBO} and subs quently failed catastrophically, as did seven (7) other units, after the 275°C stress. All failed units from this subgroup, with the exception of S/N 4737, failed due to intermetallic formations caused by thermal stress. See Appendix C, Page C-2. This test was stopped after the completion of the 275°C stress, due to the excessive number of catastrophic failures.

3.3.2 MOTOROLA

Prior to the initial 150°C stress, S/N 4793 was an h_{FE} parametric failure. It improved with the first temperature bias exposure and continued to be stable throughout the balance of the stresses. No other failures were encountered from this vendor during all subsequent stresses.

3.3.3 STATISTICAL SUMMARY

Table VI outlines the results of this temperature stress for each parameter, measurement point and vendor.

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4.0 FINAL DATA SUMMARY

Table VII summarizes the change in the mean value from the zero (Ø) hour data to the final data. Figure 1 and 2 graph the cumulative percent failures vs the temperature stress level for TEMPERATURE STRESS I and II. Tables VIII and IX summarize the failures encountered for all three stresses. They are broken down by catastrophic failures in Table VIII and parametric failures in Table IX. The data from Table VIII was used as an input for the graphs in Figures 2 and 3.

5.0 CONCLUSIONS

Thirteen parts were destroyed by handling and 31 other parts failed for a variety of reasons. The most common of these was intermetallic formations due to exposure to temperature stress. A plot of the catastrophic failures is made in Figure 2 and Figure 3 to establish the activation energy of 1.69 eV. There were insufficent failures in the Motorola group to perform the calculations. The activation energy was arrived at using the formula:

$$E = \ln\left(\frac{t_1}{t_2}\right)\left(\frac{8.63 \times 10^{-5}\,eV}{\left(\frac{1}{T_1+273}\right)\left(\frac{1}{T_2+273}\right)}\right)$$

Texas Instruments appears more susceptible to external lead damage than Motorola although the reason was not apparent.

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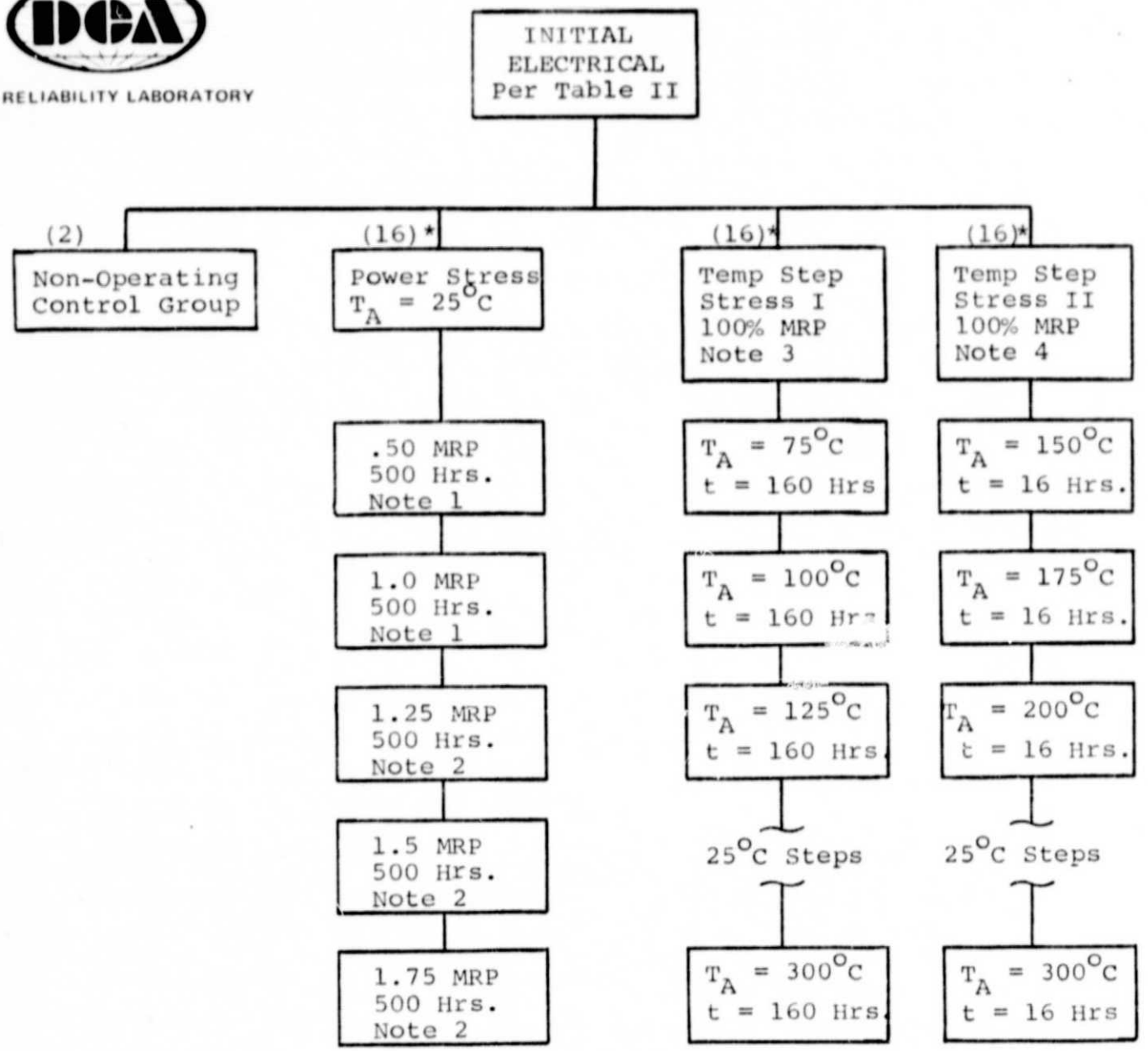
TABLE I. Test Flow Diagram.



*Quantity per manufacturer (T.I. & Motorola)

NOTES:

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

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TABLE II. Parameter and Test Conditions

PARAMETER	CONDITIONS	SPECIFICATION LIMIT MIN	SPECIFICATION LIMIT MAX	CATASTROPHIC[1] LIMIT MIN	CATASTROPHIC[1] LIMIT MAX	UNITS
I_{CBO}	Per MIL-STD-750, Method 3036, Bias Condition D V_{CB} = -50 Vdc	---	-10	---	-1000	nAdc
h_{FE}	V_{CE} = -10 Vdc I_C = -0.1 mAdc	75	---	37.5	---	---
$V_{CE(SAT)}$	I_C = -150 mAdc I_B = -15 mAdc; Pulsed	---	-0.4	---	-0.6	Vdc
$V_{CE(SAT)}$	I_C = -500 mAdc I_B = -50 mAdc; Pulsed	---	-1.6	---	-2.4	Vdc

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

TABLE III. Power Stress Burn-In Conditions

I_C = 12.0 mA	
V_{CE}	% P_D
12.5	50
25.0	100
31.2	125
37.5	150
43.7	175

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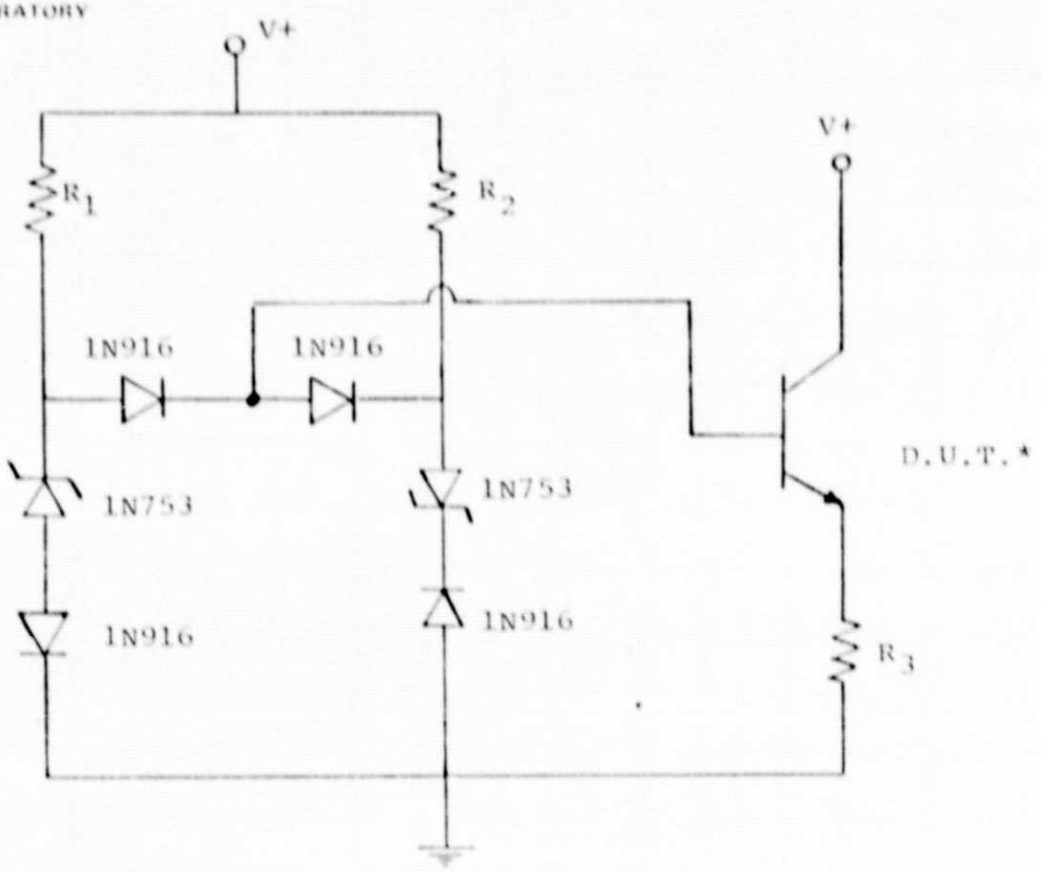
OF POOR QUALITY



$R_1 = R_2 = 800\Omega \pm 5\%$, 2W

$R_3 = 150\ \Omega$ 1%, ½W

V+ = See Table III, Page 9.

*Device Under Test

FIGURE 1. Power and Temperature Stress Circuit for JANTX2N2905A

TABLE IV

PART NUMBER JANTX2N2905A

POWER STRESS DATA SUMMARY

PARAMETER CONDITIONS AND LIMIT	ICBO 10 NA MAX. VCB -50 VDC		HFE 75 MIN. VCE = -10 VDC IC = -0.1 MADC		VCE(SAT 1)-0.4 V MAX IC = -150 MA IB = - 15 MA		VCE(SAT 2) -1.6 V MAX IC = -500 MA IB = - 50 MA	
	TEXAS INST.	MOTOROLA	TEXAS INST.	MOTOROLA	TEXAS INST.	MOTOROLA	TEXAS INST.	MOTOROLA
INITIAL DATA								
MIN VALUE	0.0 A	0.0 A	140	69.7	158 MV	135.0 MV	434.0 MV	382.0 MV
MAX VALUE	260 PA	5.35NA	222	188.0	195 MV	255.0 MV	520.0 MV	797.0 MV
MEAN	21.33PA	705.9 PA	169.5	117.8	168.6 MV	185.3 MV	466.4 MV	561.3 MV
STD. DEV.	65.00PA	1.249NA	20.58	33.89	9.258MV	36.75 MV	20.75MV	128.5 MV
△MEAN VALUE INITIAL TO POST STRESS								
50% POWER								
50 HOURS	0 A	- 20.0PA	0.4	0	-4.9 MV	-4.10 MV	-23.4 MV	-25.4 MV
150 HOURS	0.67 PA	68.2PA	2.6	0.5	9.9 MV	2.5 MV	21.4 MV	10.4 MV
250 HOURS	8.67 PA	- 25.9PA	3.1	2.0	0.2 MV	-0.6 MV	1.0 MV	- 1.0 MV
500 HOURS	-3.47 PA	-124.7PA	1.9	1.9	-0.1 MV	-0.7 MV	0 MV	- 1.7 MV
100% POWER								
550 HOURS	123.67 PA	-139.4PA	2.5	6.9	0.5 MV	2.2 MV	2.7 MV	- 1.2 MV
650 HOURS	-4.90 PA	45.3PA	4.3	11.8	0.8 MV	2.4 MV	5.2 MV	-13.5 MV
750 HOURS	-1.33 PA	-128.8PA	3.9	16.4	-0.7 MV	-0.8 MV	-1.0 MV	- 2.7 MV
1000 HOURS	5.81 PA	- 71.8PA	4.1	12.9	0.1 MV	-0.2 MV	1.8 MV	1.2 MV
125% POWER								
1010 HOURS	6.53 PA	- 38.3PA	5.1	16.7	14.1 MV	3.6 MV	20 MV	12.3 MV
1025 HOURS	3.67 PA	-123.0PA	4.9	17.2	-0.7 MV	-1.3 MV	- 1.7 MV	- 3.1 MV
1050 HOURS	-4.19 PA	-200.3PA	4.4	16.5	-0.6 MV	-0.5 MV	- 1.2 MV	- 0.9 MV
1150 HOURS	17.24 PA	-269.4PA	8.3	20.2	-0.1 MV	-1.3 MV	0.1 MV	- 2.9 MV
1250 HOURS	27.76 PA	-200.0PA	-1.1	17.1	2.7 MV	3.8 MV	9.1 MV	20.9 MV
1500 HOURS	0.49 PA	-388.8PA	1.2	34.7	-0.1 MV	-5.1 MV	1.0 MV	6.1 MV

CONTINUED

TABLE IV (Continued)

PART NUMBER JANTX2N2905A

Power Stress Data Summary

PARAMETER CONDITIONS AND LIMIT	ICBO 10 NA MAX. VCB -50 VDC		HFE 75 MIN. VCE = -10 MA IC = -0.1 MADC		VCE(SAT 1)-0.4V MAX IB =- 15 MA		VCE(SAT 2) -1.6V MAX. IC = -500 MA IB = - 50 MA	
	TEXAS INSTR.	MOTOROLA	TEXAS INSTR.	MOTOROLA	TEXAS INSTR.	MOTOROLA	TEXAS INSTR.	MOTOROLA
INITIAL DATA								
MIN VALUE	0.0 A	0.0 A	140.0	69.7	158.0 MV	135.0 MV	434.0 MV	382.0 MV
MAX VALUE	260 PA	5.35 NA	222.0	188.0	195.0 MV	255.0 MV	520.0 MV	797.0 MV
MEAN	21.33 PA	705.9 PA	169.5	117.8	168.6 MV	185.3 MV	466.4 MV	561.3 MV
STD. DEV.	65.0 PA	1.249NA	20.58	33.89	9.258MV	36.75 MV	20.75 MV	128.5 MV
△MEAN VALUE INITIAL TO POST STRESS								
150% POWER								
1510 HOURS	13.22 PA	-474.5 PA	3.6	38.6	0.1	- 6.7	1.1	-2.2
1525 HOURS	9.67 PA	-411.6 PA	-2.2	34.9	-2.1	- 3.4	-0.1	12.1
1550 HOURS	18.67 PA	-357.4* PA	-3.1	31.12*	-1.9	- 0.4*	-0.4	25.2*
1650 HOURS	21.53 PA	-485.9 PA	-3.9	35.9	-3.3	- 2.3	-3.5	-5.5
1750 HOURS	32.96 PA	-448.4 PA	-4.1	38.6	-1.0	- 1.0	2.5	-10.3
2000 HOURS - Note 1	TEST STOPPED	-383.9 PA	TEST STOPPED	38.5	TEST STOPPED	- 0.3	TEST STOPPED	13.1
175% POWER								
2010 HOURS	TEST	-454.2 PA	TEST	39.8	TEST	- 3.8	TEST	-2.2
2025 HOURS	STOPPED	-478.4 PA	STOPPED	38.5	STOPPED	- 2.4	STOPPED	6.7
2050 HOURS	"	-369.2 PA	"	40.0	"	- 2.8	"	6.3
2150 HOURS	"	-449.2 PA	"	39.8	"	- 7.2	"	-5.8
2250 HOURS	"	-417.9 PA	"	41.8	"	1.1	"	-13.2
2500 HOURS	"	-383.9 PA	"	25.5	"	-982.7	"	-961.7
FINAL DATA /HOURS	1750	2500	1750	2500	1750	2500*	1750	2500*
MIN VALUE	0.0 A	10.00 PA	146.0	0	159.0 MV	148.0 MV	450.0 MV	424.0 MV
MAX VALUE	380.0 PA	1.340NA	186.0	224.0	177.0 MV	268.0 MV	488.0 MV	838.0 MV
MEAN	54.29 PA	322.0 PA	165.4	143.3	167.6 MV	187.9 MV	468.9 MV	582.2 MV
STD. DEV.	133.0 PA	384.0 PA	13.36	56.58	5.123MV	40.29 MV	11.58 MV	143.3 MV

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

* CATASTROPHIC REJECT(S) REMOVED FROM DATA

TABLE V

PART NUMBER JANTX2N2905A

Temperature Stress I (160 Hour) Data Summary

PARAMETER CONDITIONS AND LIMIT	ICBO 10 NA MAX. VCB = -50 VDC		HFE - 75 MIN. VCE = -10 VDC IC = -0.1 MADC		VCE(SAT 1)-0.4 V MAX IC = -150 MA IB = - 15 MA		VCE(SAT 2) -1.6 V MAX. IC = -500 MA IB = - 50 MA	
	TEXAS INSTRU.	MOTOROLA	TEXAS INSTR.	MOTOROLA	TEXAS INSTRU.	MOTOROLA	TEXAS INSTRU.	MOTOROLA
INITIAL DATA								
MIN VALUE	340.0 PA	380.0 PA	99.0	83.7	159.0 MV	140.0 MV	442.0 MV	387.0 MV
MAX VALUE	430.0 PA	2.54 NA	237.0	184.0	194.0 MV	246.0 MV	554.0 MV	1430 MV
MEAN	376.9 PA	1.044NA	178.9	134.4	172.1 MV	186.0 MV	487.0 MV	586.2 MV
STD. DEV.	27.55 PA	710 PA	31.61	28.26	8.54 MV	30.14 MV	26.07 MV	238.0 MV
△ MEAN VALUE 160 HRS. STEPS INITIAL TO POST STRESS								
TOTAL HOURS								
160 + 75°C	128.7 PA	168 PA	- 2.2	21.3	-2.4 MV	- 3.1 MV	- 2.4 MV	- 1.3 MV
320 +100°C	141.9 PA	53 PA	- 0.8	20.5	-2.0 MV	- 2.8 MV	- 1.3 MV	- 0.9 MV
480 +125°C	265.0 PA	93 PA	- 1.4	21.5	-2.8 MV	- 3.2 MV	- 2.9 MV	- 2.4 MV
640 +150°C	166.8 PA	170 PA	- 1.3	27.2	-4.8 MV	- 3.1 MV	+ 0.2 MV	3.8 MV
800 +175°C	121.8 PA	7 PA	- 7.0	28.9	-4.3 MV	- 3.1 MV	+ 8.1 MV	11.4 MV
960 +200°C	261.3 NA	-77.1 PA	- 11.7	29.7	-5.7 MV	- 9.9 MV	+15.3 MV	7.1 MV
1120 +250°C	297.8 UA	-115.3 PA	-304.5	16.2	-6.2 MV	-16.5 MV	+60.3 MV	7.6 MV
1280 +275°C	*499.4 NA	-67.8 PA	-319.7	13.8	-13.1MV	-24.1 MV	+91.0 MV	17.5 MV
1440 +275°C	TEST STOPPED	* 1.04NA	TEST STOPPED	10.1	TEST STOPPED	-34.9 MV	TEST STOPPED	-84.3 MV
1600 +300°C		* 1.09NA		14.4		-36.2 MV		-89.1 MV
FINAL DATA								
LAST STRESS Temp.	250°C	300°C	250°C	300°C	250°C	300°C	250°C	300°C
MIN VALUE	480 PA	520 PA	143	98	156 MV	128 MV	460 MV	384 MV
MAX VALUE	999 NA	431 NA	999	199	346 MV	174 MV	1040 MV	727 MV
MEAN	499.8NA	34.16NA	498	148.8	185 MV	149.8 MV	578 MV	497 MV
STD. DEV.	499.2NA	114.6 NA	408	28.96	54 MV	15.1 MV	176 MV	98.6MV

* CATASTROPIC REJECT(S) REMOVED FROM DATA

TABLE VI

PART NUMBER JANTX2N2905A

TEMPERATURE STRESS II (16 Hour) Data Summary

PARAMETER CONDITIONS AND LIMIT	ICBO 10 NA MAX. VCB = -50 VDC		HFE 75 MINIMUM VCE = -10 VDC IC = -0.1 MADC		VCE(SAT 1) -0.4VMAX IC = -150 MA IB = - 15 MA		VCE(SAT 2) -1.6V MAX IC = -500 MA IC = -50 MA	
	TEXAS INSTR.	MOTOROLA	TEXAS INSTR.	MOTOROLA	TEXAS INSTR.	MOTOROLA	TEXAS INSTR.	MOTOROLA
INITIAL DATA								
MIN VALUE	360 PA	180 PA	159.0	71.0	143.0 MV	148.0 MV	402 MV	398.0 MV
MAX VALUE	4.17 NA	6.32 NA	233.0	164.0	177.0 MV	275.0 MV	506 MV	787.0 MV
MEAN	608.1 PA	1.651 NA	180.3	127.7	154.3 MV	194.4 MV	454.8 MV	591.3 MV
STD. DEV.	919.7 PA	1.757 NA	18.7	27.42	10.56 MV	29.26 MV	35.0 MV	92.7 MV
△ MEAN VALUE 16 HRS. STEPS INITIAL TO POST STRESS								
TOTAL TIME								
16 +150°C	-90 PA	.046 NA	0.5	4.6	-2.4 MV	-4.1 MV	9.1 MV	-3.2 MV
32 +175°C	-20.6 PA	.045 NA	- 1.4	10.9	-1.7 MV	-5.5 MV	6.5 MV	-4.4 MV
48 +200°C	88.8 PA	-.267 NA	-10.0	14.9	-2.3 MV	-4.4 MV	11.4 MV	-24.5 MV
64 +225°C	62.34 PA	-.249 NA	-16.7	20.9	-2.8 MV	-10.6 MV	13.3 MV	-20.6 MV
80 +250°C	528.9 PA	-.189 NA	-22.8	23.8	-4.3 MV	-18.3 MV	4.3 MV	-19.6 MV
96 +275°C	532.6 PA	-.169 NA	* 5.8	21.5	-1.7 MV	-31.9 MV	21.3 MV	-30.7 MV
112 +300°C	TEST STOPPED	-.296 NA	TEST STOPPED	16.1	TEST STOPPED	-34.6 MV	TEST STOPPED	- 1.5 MV
FINAL DATA								
LAST STRESS 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	141.0 MV	120.0 MV	406.0 MV	362.0 MV
MAX VALUE	999 NA	5.64 NA	999	198.0	184.0 MV	190.0 MV	617.0 MV	793.0 MV
MEAN	533.2 NA	1.355 NA	325.0	143.8	157.6 MV	159.8 MV	476.1 MV	589.8 MV
STD. DEV.	497.9 NA	1.523 NA	341.6	32.05	12.52MV	15.53MV	56.43MV	118.5 MV

* CATASTROPHIC REJECTS REMOVED FROM DATA.

TABLE VII

PART NUMBER JANTX2N2905A

Final Data Summary

PARAMETER	SPECIFICATIONS LIMIT MIN	SPECIFICATIONS LIMIT MAX	UNITS	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE T.I. POWER STRESS	AVERAGE Δ IN MEAN VALUE MOTOROLA POWER STRESS	AVERAGE Δ IN MEAN VALUE T.I. TEMP STRESS I	AVERAGE Δ IN MEAN VALUE MOTOROLA TEMP STRESS I	AVERAGE Δ IN MEAN VALUE T.I. TEMP STRESS II	AVERAGE Δ IN MEAN VALUE MOTOROLA TEMP STRESS II
ICBO	___	-10	NA	.335	+ .0146	- .2588	+ .2108	+ .2261	+ .1837	- .1500
HFE	75	___	__	176.	+ 1.89	+23.76	-5.46	+20.36	-7.43	+16.10
VCE(SAT)	___	-0.4	V	.166	+ .0007	- .0010	- .0003	- .0137	- .0025	- .0156
VCE(SAT)	___	-1.6	V	.469	+ .0018	+ .0043	+ .0216	- .0930	+ .0101	- .0149

NOTE: ALL CATASTROPHIC REJECTS REMOVED FROM DATA.

TABLE VIII STEP STRESS Catastrophic FAILURE SUMMARY JAN TX2N2905A

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.				
100 hr.				
100 hr.				
250 hr.				
100% 50 hr.				
100 hr.				
100 hr.				
250 hr.				
125% 10 hr.				
15 hr.				
25 hr.				
100 hr.				
100 hr.				
250 hr.			2	4
150% 10 hr.				
15 hr.				
25 hr.			1	4
100 hr.				
100 hr.	Ø	2		
250 hr.				
175% 10 hr				
15 hr.				
25 hr.				
100 hr.				
100 hr.				
250 hr.				

GROUP II 160 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C				
100° C				
125° C				
150° C				
175° C				
200° C	1	1		
225° C	6	1	1	3
250° C	5	1		
275° C	Test Stopped		1	1
300° C				

GROUP III 16 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150° C				
175° C				
200° C				
225° C	1	3		
250° C				
275° C	8	1		
300° C	Test Stopped			

NOTES:

MFR A = Texas Instruments
B = Motorola

1. $I_{CBO} \geq 1000$ nA
2. Test stopped due to excessive mechanical failures.
3. $h_{fE} \leq 37.5$
4. Open

TABLE IX STEP STRESS Parametric FAILURE SUMMARY JAN TX2N2905A

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.			2	1
100 hr.				
100 hr.	1	2		
250 hr.				
100% 50 hr.				
100 hr.				
100 hr.				
250 hr.				
125% 10 hr.				
15 hr.				
25 hr.				
100 hr.	1	3		
100 hr.	2	3	1	3
250 hr.				
150% 10 hr.	1	3		
15 hr.	2	3		
25 hr.	1	3		
100 hr.			1	3
100 hr.	Test Stopped			
250 hr.				
175% 10 hr.				
15 hr.				
25 hr.				
100 hr.			1	3
100 hr.			1	3
250 hr.			1	3

GROUP II 160 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C				
100° C				
125° C				
150° C				
175° C				
200° C	1	7		
225° C				
250° C			1	5
275° C	Test Stopped		1	6
300° C				

GROUP III 16 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150° C				
175° C				
200° C				
225° C				
250° C	2	4		
275° C				
300° C	Test Stopped			

NOTES:

MFR A = Texas Instruments

B = Motorola

1. S/N 4761 & 4767 h_{fE} failures.
2. S/N 4712 missing
3. Lead(s) broken - Electrically good.
4. S/N 4739 & 4747 h_{fE} failures.
5. S/N 4780 V_{CE2} failure.
6. S/N 4784 I_{CBO} failure.
7. S/N 4734 I_{CBO} failure.

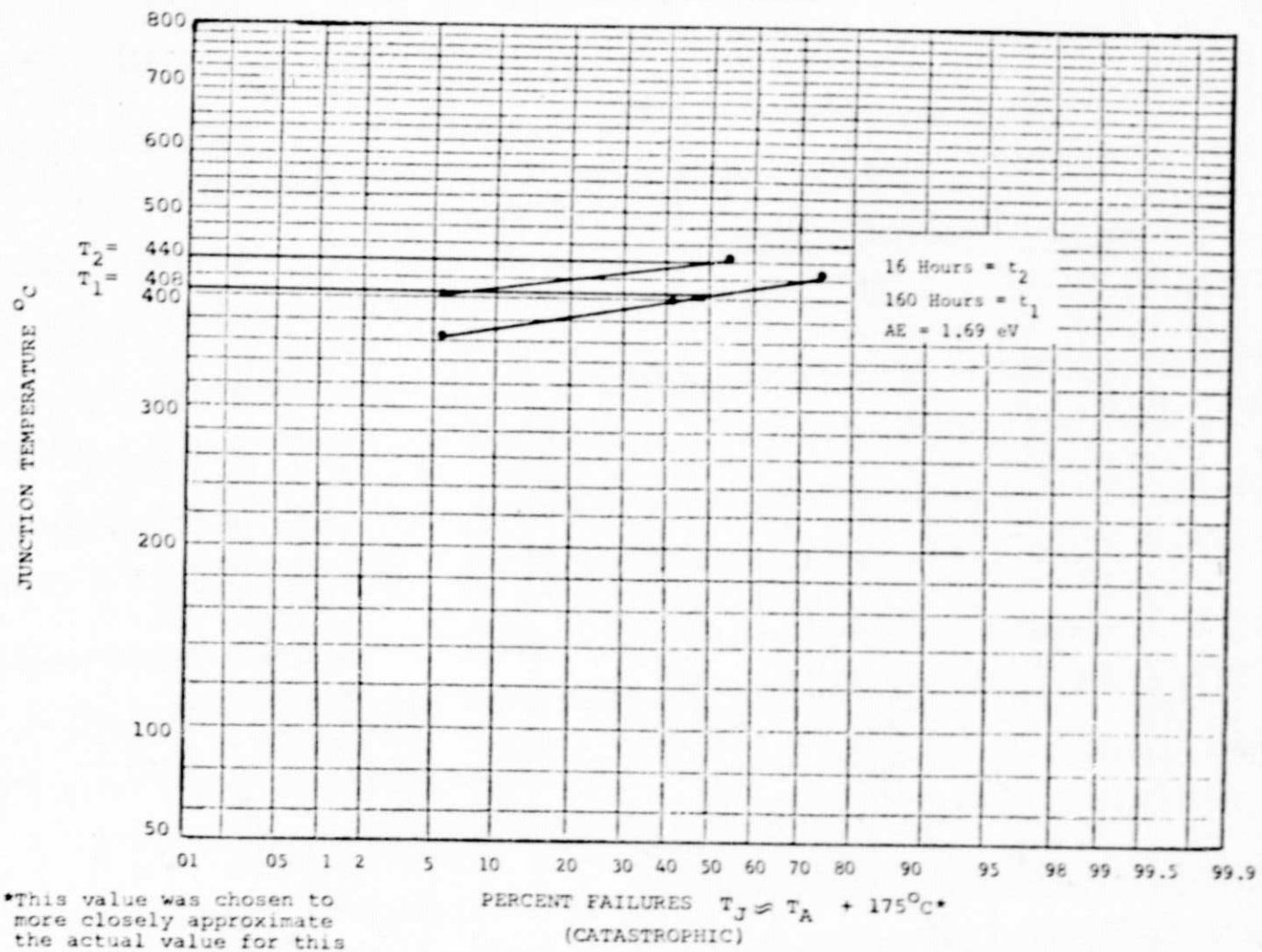
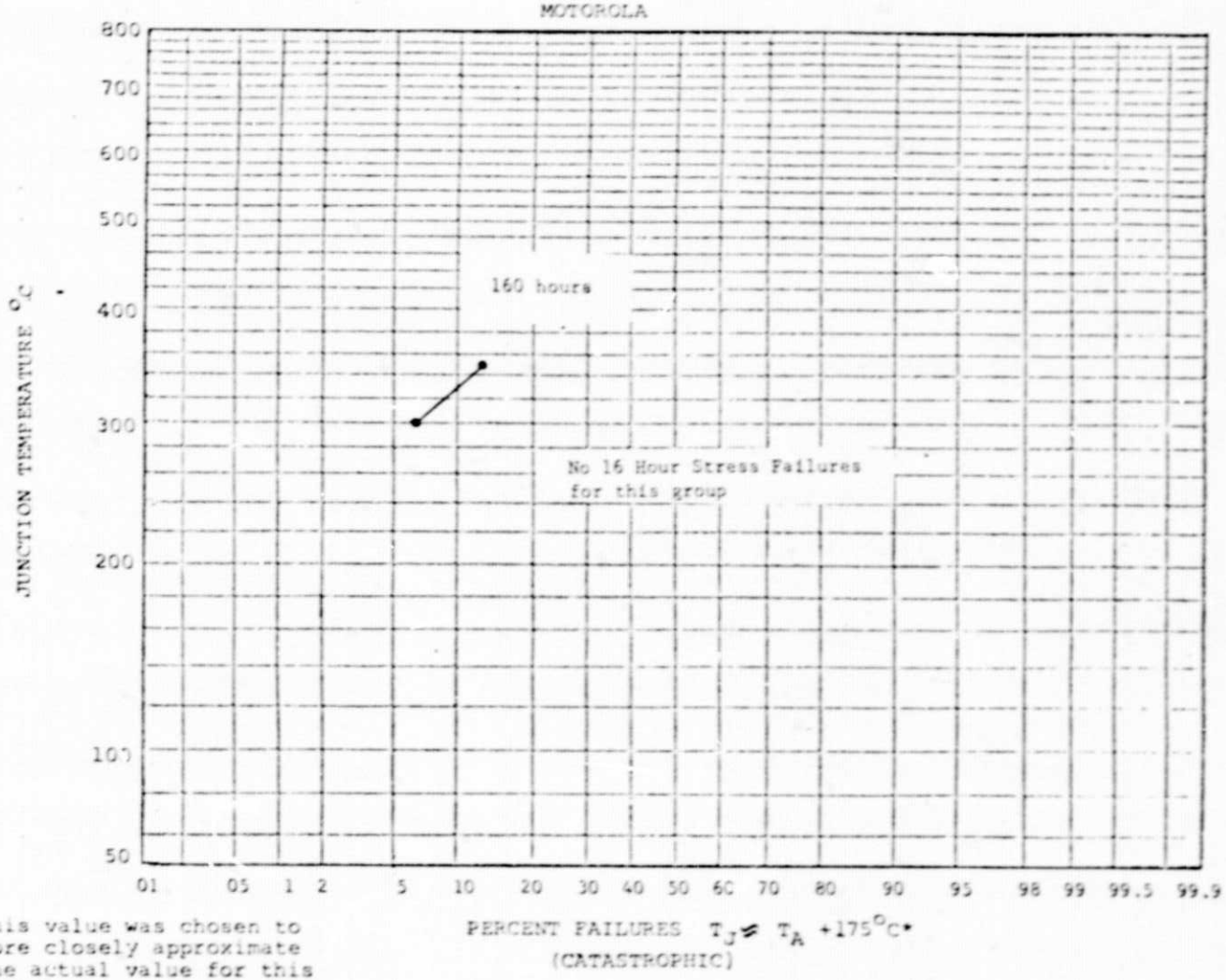


FIGURE 2. Cumulative Failure Distribution
(Texas Instruments)



*This value was chosen to more closely approximate the actual value for this part type.

FIGURE 3. Cumulative Failure Distribution
(Motorola)

APPENDIX A

FAILURE ANALYSIS - POWER STEP STRESS

DCA

MSFC STEP-STRESS TEST -
FAILURE ANALYSIS- TRANSISTORS
(POWER)

Date 26 April 1978

J/N 2CN242-04A P/N 2N2905 (JAN) MFR: Texas Instruments

FAILURE VERIFICATION: Max= 10nA Min = 75

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -uA- @ V_{CB} = 50 V.	BV_{EBO} -volts-	BETA @ I_C= 100uA; V_{CE} = 10 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ.@ test sequence #:	INITIAL REJ. FOR:
4706	72	86	0.2 nA	7.3	185	0.78	35	catastrophic-visual (150% power, 50 hrs.)
4708	70S	100	0.2 nA	7.3	122	0.76	25	catastrophic-visual (125% power, 150 hrs.)
4711	70	108	1.0 nA	7.6	172	0.78	33	catastophic-visual (150% power, 25 hrs.)

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 = hysteresis

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

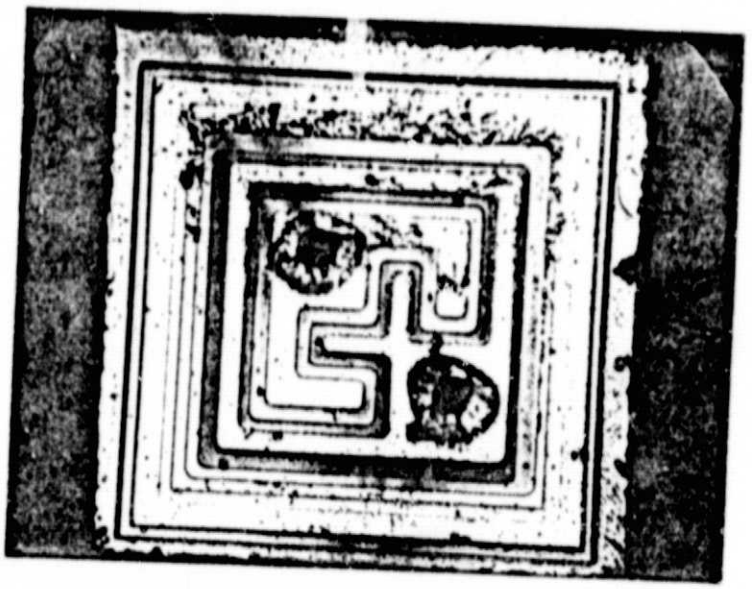


FIGURE A-1
S/N 4711. Magnification 144X. T.I. die geometry. (The dark areas in the metallization are mechanically disturbed.)

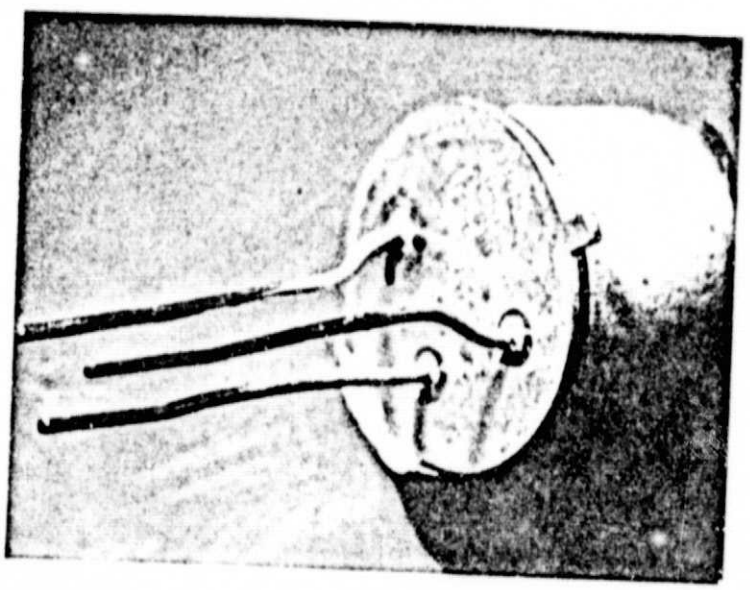


FIGURE A-2
S/N 4760. Magnification 5X. Typical lead bending for insertion in burn-in board.

DCA

MSFC STEP-STRESS TEST

FAILURE ANALYSIS- TRANSISTORS

(POWER)

Date 26 April 1978

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

FAILURE VERIFICATION: Max = Min =

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -nA- @ V_{CB} = 50 V.	BV_{EBO} -volts-	BETA @ I_C = 100 mA; V_{CE} = 10 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ. @ test sequence #:	INITIAL REJ. FOR:
	Max = 10 nA				Min = 75			
4761	75	96	0.4 nA	7.2	100	0.78	1-5	hFE (50% power 150 hrs
4755	10→33 [1]	90	0.4 nA	7.0	159	0.75		catastrophic (E. lead off) (175% power. 250 hrs.)
4769	open	short	⊶	open	--	--	35	catastropic (150% power, 50 hrs.)

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

The other 2 samples show no significant internal anomalies.

S/N 4770 has a missing external emitter lead. This sublot contains 9 devices with missing leads, including 1 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 μ-seconds. 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 exhibit 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 = 9 ea.

Failure Analysis = 3 ea.

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

H = hysteresis

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

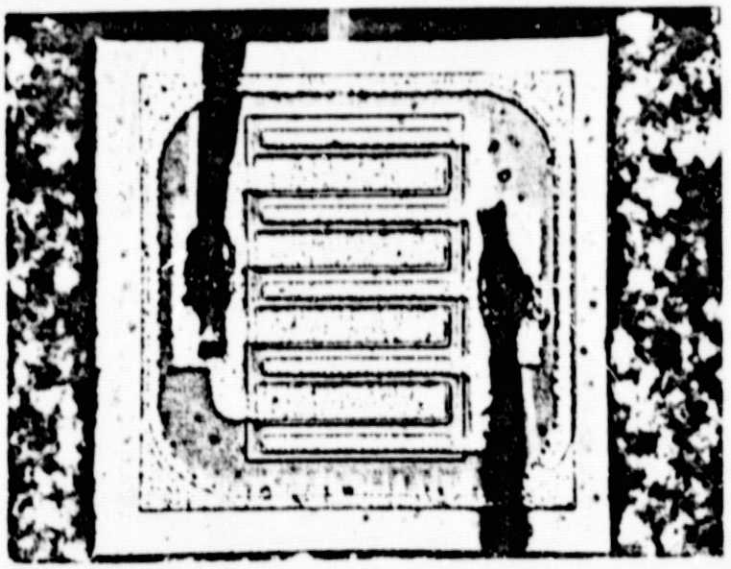


FIGURE A-3
S/N 4761. Magnification 144X. Typical Motorola Instruments die geometry.

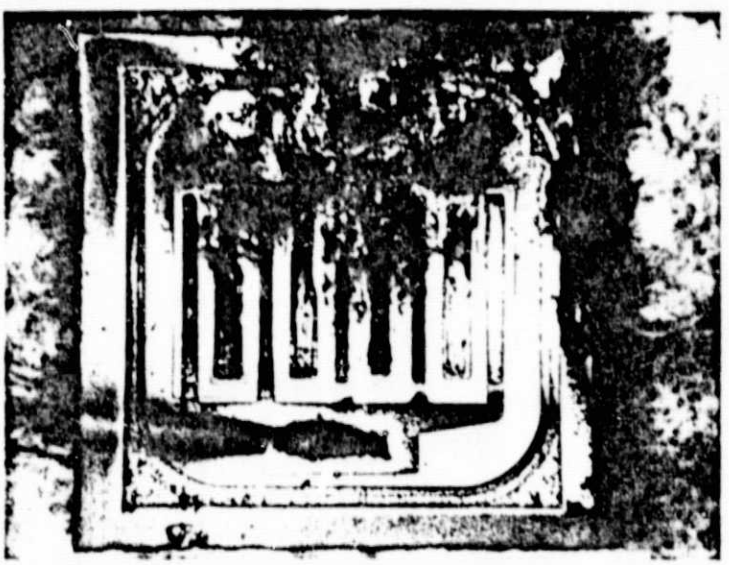


FIGURE A-4
S/N 4769. Magnification 144X. Motorola device destroyed by electrical overstress.

DCA RELIABILITY LABORATORY

A P P E N D I X B

FAILURE ANALYSIS - TEMPERATURE STRESS I

DCA

MSFC STEP-STRESS TEST

FAILURE ANALYSIS- TRANSISTORS

(TEMPERATURE STRESS I) Date 27 April 1978

J/N 2CN242-04B P/N 2N2905 (PNP) MFR: Texas Instruments

FAILURE VERIFICATION: Max. = 10 nA Min. = 75

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -uA- @ V_{CB} = 50 V.	BV_{EBO} -volts-	BETA @ I_C = 100uA; V_{CE} = 10 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ.@ test sequence #:	INITIAL REJ. FOR:
4722	0.58	4.8R	1.03 mA	7.2	R	0.8	15	I_{CBO}, h_{FE} (100%, 160 Cat. 225° C
4725	13.5	56S	5.0 uA	7.2	54	0.79	17	I_{CBO} (100% 160 hrs. 250° C
4727	0.6	13.5R	600 uA	7.3	R	0.78	15	I_{CBO}, h_{FE} (100%, 160 225° C

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.

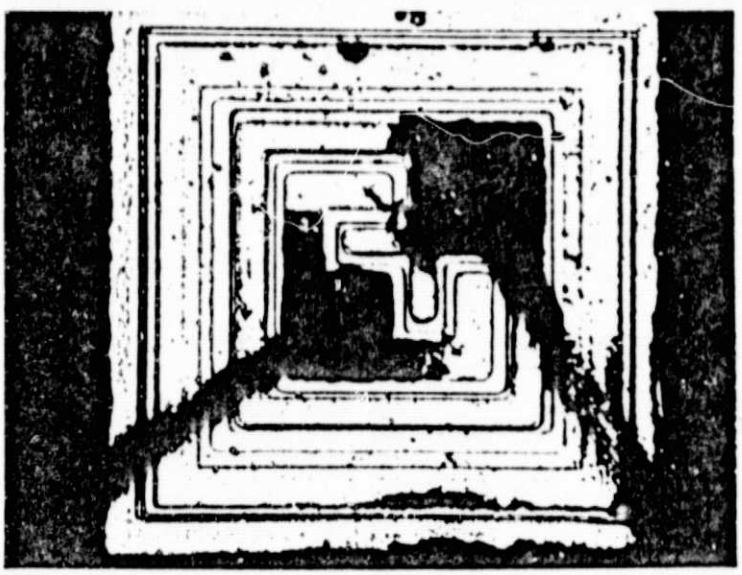


FIGURE B-1
Typical Texas Instruments die appearance.
S/N 4722. Magnification 160 X

*Beta trace present. Cannot meet stated test conditions.
**Beta trace very leaky. H = hysteresis
S = soft D = drift Inv = inversion Uns = unstable R = resistive

MSFC STEP-STRESS TEST

FAILURE ANALYSIS- TRANSISTORS

(TEMPERATURE STRESS II) Date 28 April 1978

J/N 2CN242-04 B P/N 2N2905 (PNP) MFR: Motorola

FAILURE VERIFICATION:

max= 10 nA min=75

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -uA- @ V_{CB} = 50 V.	BV_{EBO} -volts-	BETA @ I_C= 100 uA; V_{CE} = 10 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ.@ test sequence #:	INITIAL REJ. FOR:
4772	50→80H	97	0.4 nA	7.2	4.6	0.78	15	h_{FE} (100%,160 hrs, 225° C.
4780	80 H	92	0.4 nA	7.1	179	0.78	19	V_{CE} (100%,160 hrs,250°
			V_{BCO} @ 10 mA= 0.75. $V_{CEO(sat)}$ @ 150 mA= 0.35.					
4784	42→82H	104	0.5 uA	7.1	158	0.76	19	I_{CBO} (100%,160 hrs,275°

The higher BVCEO figures were measured after de-lidding.

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 fig. B-3.)

CONCLUSIONS:

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 beta fall-off 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 impureties under the influence of the high power and temperature used to stress the device. The change (increase) in collector-emmitter 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 = 150 mA 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.

H = hysteresis

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

S/N 4784

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

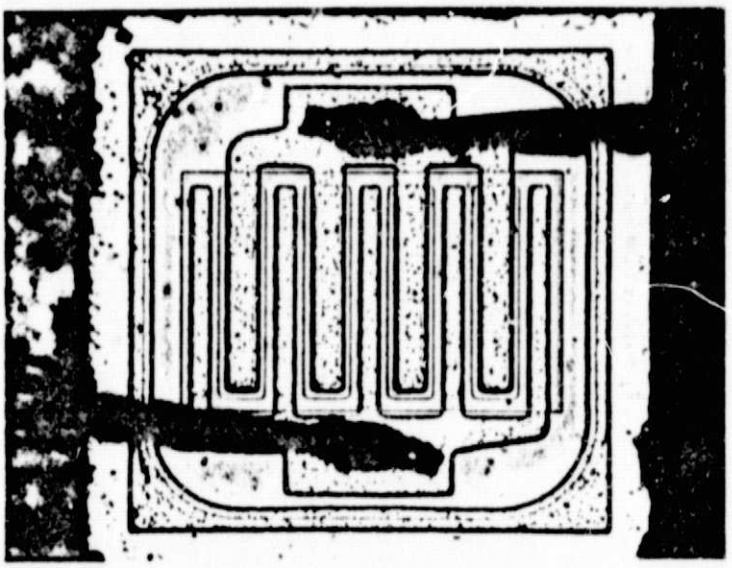


FIGURE B-2
S/N 4772. Magnification 160 X. Typical Motorola die geometry.

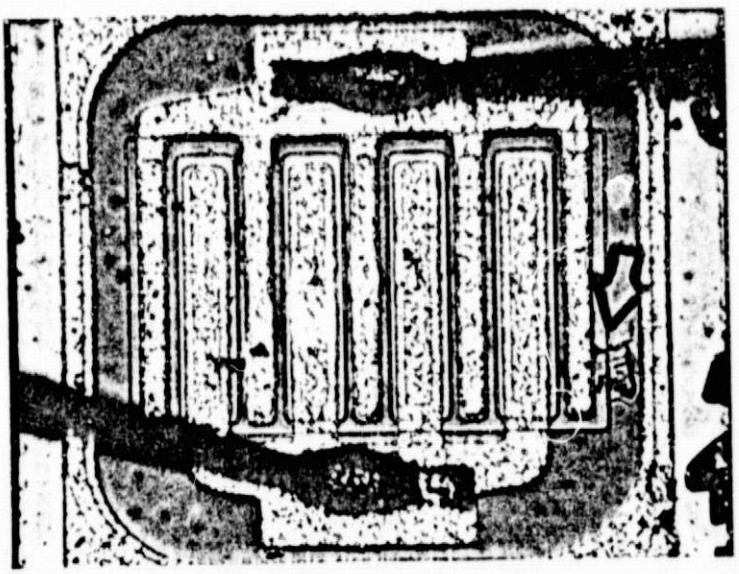


FIGURE B-3
S/N 4784. Magnification 200 X. Arrow indicates collector-base junction defect on this Motorola sample.

DCA RELIABILITY LABORATORY

A P P E N D I X C

FAILURE ANALYSIS - TEMPERATURE STRESS II

MSFC STEP-STRESS TEST

FAILURE ANALYSIS- TRANSISTORS

(TEMPERATURE STRESS II) Date 20 March 1978

J/N 2CN242-04C P/N 2N2905A MFR: Texas Instruments

FAILURE VERIFICATION: Max. = 10 nA Min. = 75

S/N	BV_{CEO} -volts- * See note below.	BV_{CBO} -volts-	I_{CBO} -uA- @ V_{CB} = 50 V.	BV_{EBO} -volts-	BETA I_B= 0.1uA; V_{CE} = 10 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ. @ Seq.#	INITIAL REJ. FOR:
E014737	35	100	<10nA	7.0	160	0.75	-not	rejected-
739	6.7 S	15 S	152.	7.2	25	0.70	11 (250°)	h_{FE}, I_{CBO}
745	80. uns	84 uns	1.0	7.1	10	0.65	09 (225°)	catastrophic
747	2.5 S	16 S	120.	7.2	*	0.68	11 (250°)	hFE, I_{CBO}
752	1.8 S	4.5	600.	7.4 R	none	0.76	15 (300°)	catastrophic

*NOTE: THE BV_{CEO} AND BV_{CBO} READINGS WERE MEASURED AT 5 uA. Actual breakdown had not been reached on S/N 739, 747 and 752. The I_{CBO} readings were also below breakdown voltage.

INTERNAL VISUAL INSPECTION:

All samples have severe intermetallic formation surrounding the base and emitter lead wires. No other significant defects were visible. (See fig. 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 fig. 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.

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

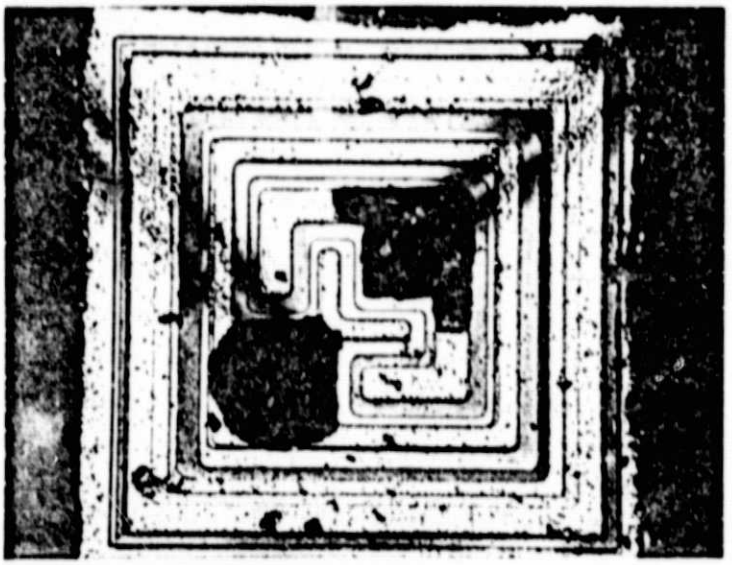


FIGURE C-1
S/N 739. Magnification 152 X. Typical overall die view. Dark areas of gold/aluminum intermetallics surround the emitter and base ball bonds.

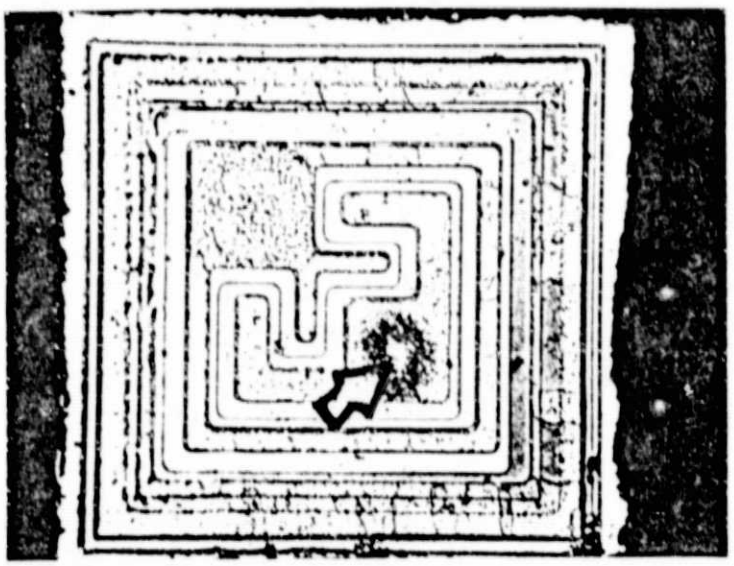


FIGURE C-2
S/N 739. Magnification 152 X. Same die as fig. 1 after stripping the metallization and wire bonds. Arrow indicates damaged oxide which was attacked by the intermetallics.