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TRANSISTOR

STEP STRESS TESTING PROGRAM

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FINAL REPORT
FOR

JANTX2N3637

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Prepared
For

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FOREWORD

This 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 transistors, diodes, and FETS was 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 varieties of discrete devices, as well as to determine which type of stress should be applied to a particular type of device or design.

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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 JANTX2N3637 manufactured by Transitron and Motorola.

A total of 48 samples from Transitron and 41 samples from Motorola were 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 units, 16 from Transitron and 14 from Motorola were submitted to the Power Stress Process. The transistors were stressed in 500-hour steps at 50, 100, 125, 150, and 175 percent of maximum rated power 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.

2.4 Group II - Temperature Stress I

Thirty units, 17 from Transitron and 13 from Motorola, 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

Twenty-nine units, 15 from Transitron and 14 from Motorola 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

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

electrical parameters after each temperature step. See Table 1.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 Transitron. The Transitron sample lot completed 1500 hours of Group I Testing before the lot was stopped because more than 50% of the devices failed. The first failure occurred 150 hours into the 125% MRP step. Serial number 1788 failed the maximum I_{CBO} limit. The last 12 failures occurred 500 hours into the 125% MRP step. Serial numbers 1789 and 1795 failed the maximum h_{FE} limit. Serial numbers 1787, 1794, and 1800 failed the maximum I_{CBO} limit. Serial numbers 1792, 1797, 1798, and 1801 failed the maximum V_{CE1}, V_{CE2}, and minimum h_{FE} limits. Serial numbers 1791 and 1796 failed the maximum V_{CE1}, and V_{CE2} limits. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 1.537mA from an initial mean of 3.494nA to a final mean of 1.537mA.

2) The mean value for V_{CE1} changed 4.554V from an initial mean of 88.88mV to a final mean of 4.643V.

3) The mean value for V_{CE2} changed 4.542V from an initial mean of 142.2mV to a final mean of 4.684V.

4) The mean value for h_{FE} changed 382.3 from an initial mean of 112.1 to a final mean of 494.4.

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-hour Group I Testing with three catastrophic failures. The first failure occurred 500 hours into the 125% MRP step. Serial number 1844 failed the maximum V_{CE1}, V_{CE2}, and minimum h_{FE} limits. The next failure occurred 50 hours into the 150% MRP step. Serial number 1868 failed the maximum I_{CBO} limit. The last failure occurred 500 hours into the 175% MRP step. Serial number 1870 failed the maximum I_{CBO}, $V_{CE(SAT)1}$, $V_{CE(SAT)2}$, and minimum h_{FE} limits. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 8.325mA from an initial mean of 3.394nA to a final mean of 8.325mA.

2) The mean value for $V_{CE(SAT)1}$ changed 824.5mV from an initial mean of 98.71mV to a final mean of 923.2mV.

3) The mean value for $V_{CE(SAT)2}$ changed 819.0mV from an initial mean of 139.3mV to a final mean of 958.3mV.

4) The mean value for h_{FE} changed 8.58 from an initial mean of 93.57 to a final mean of 84.99.

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 Transitron and Motorola.

3.2 Group II - Temperature Stress I

3.2.1 Transitron. The Transitron sample lot completed 1440 hours of Group II Testing before it was stopped because of a failure rate of more than 50% of the lot. The first failure occurred 160 hours into the 125°C-temperature step. Serial number 1810 failed the maximum h_{FE} limit. The next failures occurred 160 hours into the 225°C-temperature step. Serial numbers 1804 and 1815 failed the minimum h_{FE} limit. Serial number 1817 failed the maximum I_{CBO}, $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ limits. The next failures occurred 160 hours into the 250°C-temperature step. Serial number 1803 failed the maximum I_{CBO} and minimum h_{FE} limits. Serial number 1807 failed the maximum I_{CBO}, $V_{CE(SAT)1}$, $V_{CE(SAT)2}$ and minimum h_{FE} limits. Serial number 1837 failed the minimum h_{FE} limit. The last failures occurred 160 hours into the 275°C-temperature step. Serial numbers 1813 and 1818 failed the maximum I_{CBO} limit. Serial number 1805 failed the minimum h_{FE} limit. Serial number 1812 failed the maximum I_{CBO1}, $V_{CE(SAT)1}$, and $V_{CE(SAT)2}$ limits. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 2.997µA from an initial mean of 1.168nA to a final mean of 2.998µA.

2) The mean value for $V_{CE(SAT)1}$ changed 990.5mV from an initial mean of 92.47mV to a final mean of 1.083V.

3) The mean value for $V_{CE(SAT)2}$ changed 655.8mV from an initial mean of 158.0mV to a final mean of 813.8mV.

4) The mean value for h_{FE} changed 159.0 from an initial mean of 110.5 to a final mean of 269.5.

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 10 catastrophic failures. The first failure occurred 160 hours into the 225°C-temperature step. Serial number 1882 failed the maximum I_{CBO}, $V_{CE(SAT)1}$, and $V_{CE(SAT)2}$ limits. The next failure occurred 160 hours into the 250°C-temperature step. Serial number 1854 failed the maximum I_{CBO} and minimum h_{FE} limits. The next failure occurred 160 hours into the 275°C-temperature step. Serial number 1881 failed the minimum h_{FE} limit. The last failures occurred 160 hours into the 300°C-temperature step. Serial numbers 1851 and 1879 failed the maximum I_{CBO}, $V_{CE(SAT)1}$, and $V_{CE(SAT)2}$, and minimum h_{FE} limits. Serial numbers 1852 and 1853 failed due to excessive I_{CBO} leakage. Serial number 1875 failed the maximum $V_{CE(SAT)1}$ and minimum h_{FE} limits. Serial numbers 1876 and 1878 failed the maximum I_{CBO}, $V_{CE(1)}$, and $V_{CE(2)}$ limits. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 6.136μA from an initial mean of 2.531nA to a final mean of 6.139μA.

2) The mean value for $V_{CE(SAT)1}$ changed 4.710V from an initial mean of 102.2mV to a final mean of 4.812V.

3) The mean value for $V_{CE(SAT)2}$ changed 3.358V from an initial mean of 148.7mV to a final mean of 3.507V.

4) The mean value for h_{FE} changed 331.3 from an initial mean of 93.37 to a final mean of 424.7.

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

3.2.3 Statistical Summary - Group II. Table 5 outlines the results of Group II - Temperature Stress I Testing for each of the four electrical parameters and all measurement points for both Transitron and Motorola.

3.3 Group III - Temperature Stress II

3.3.1 Transitron. The Transitron sample lot completed the entire 112 hours of Group III Testing with a total of 10 catastrophic failures. The first failures occurred 16 hours into the 225°C-temperature step. Serial numbers 1822, 1828, and 1829 failed due to excessive I_{CBO} leakage. Serial number 1827 failed the maximum $V_{CE(SAT)2}$ limit. The next failures occurred 16 hours into the 275°C-temperature step. Serial number 1821 failed the maximum $V_{CE(SAT)2}$ and minimum h_{FE} limits. Serial number 1824 failed due to excessive I_{CBO} leakage. Serial number 1831 failed the minimum h_{FE} limit. The last failures occurred 16 hours into the 300°C-temperature step. Serial number 1825 failed the maximum $V_{CE(SAT)1}$, $V_{CE(SAT)2}$, and minimum h_{FE} limits. Serial number 1832 failed the maximum I_{CBO}, $V_{CE(SAT)1}$, and $V_{CE(SAT)2}$ and minimum h_{FE} limits. Serial number 1835 failed the maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ limits. Typical characteristics of this lot's performance were:

1) The mean value for I_{CBO} changed 2.423μA from an initial mean of 1.037nA to a final mean of 2.424μA.

2) The mean value for $V_{CE(SAT)1}$ changed 1.589V from an initial mean of 88.20mV to a final mean of 1.677V.

3) The mean value for $V_{CE(SAT)2}$ changed 2.652V from an initial mean of 143.0mV to a final mean of 2.795V.

4) The mean value for h_{FE} changed 54.93 from an initial mean of 114.5 to a final mean of 59.57.

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 hours of Group III Testing with a total of 5 catastrophic failures. The failures all occurred 16 hours into the 300°C-temperature step. Serial numbers 1857, 1883, 1886, and 1887 failed the maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ and minimum h_{FE} limits. Serial number 1858 failed the minimum h_{FE} limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 3.000pA from an initial mean of 1.911nA to a final mean of 1.914nA.

2) The mean value for $V_{CE(SAT)1}$ changed 2.828V from an initial mean of 96.64mV to a final mean of 2.925V.

3) The mean value for $V_{CE(SAT)2}$ changed 2.815V from an initial mean of 140.8mV to a final mean of 2.956V.

4) The mean value for h_{FE} changed 40.11 from an initial mean of 96.84 to a final mean of 56.73.

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 four electrical parameters and all measurement points for both Transitron 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 was 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 all three stress tests the Motorola lots out-performed the Transitron lots. The Transitron lots had to be stopped during Groups I and II Testing, whereas the Motorola lots completed the entire test times in all three groups.

The Transitron devices have two different geometries and the Motorola consist of a third type. Transitron uses a rectangular layout and a butterfly pattern. The rectangular layout is superior to the butterfly pattern because it employs "field plate" extension of the emitter metalization over the base-emitter junction. This is intended to reduce the tendency of P-channel transistors toward surface inversion. The Motorola chip appears to have a longer emitter periphery than either Transitron part. This design is superior for minimizing h_{FE} fall-off, increasing collector current, and for reducing the emitter current density.

A plot showing cumulative failure distribution for Groups II and III was drawn for the Transitron and Motorola sample lots (Figures 2 and 3 and 4 and 5 respectively). Figures 2 and 3 display the data for the Transitron sample lot used to calculate an activation energy of 1.36eV. Figures 4 and 5 display the data for the Motorola sample lot used to calculate an activation energy of 1.96eV.

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 failure point. The regression line was calculated using the least squares method.

Because of defects caused by the extreme heat of the stress tests, serial numbers 1829, 1832, 1857, 1858, and 1883 were not calculated as part of the regression line.

The activation energy was calculated from the formula:

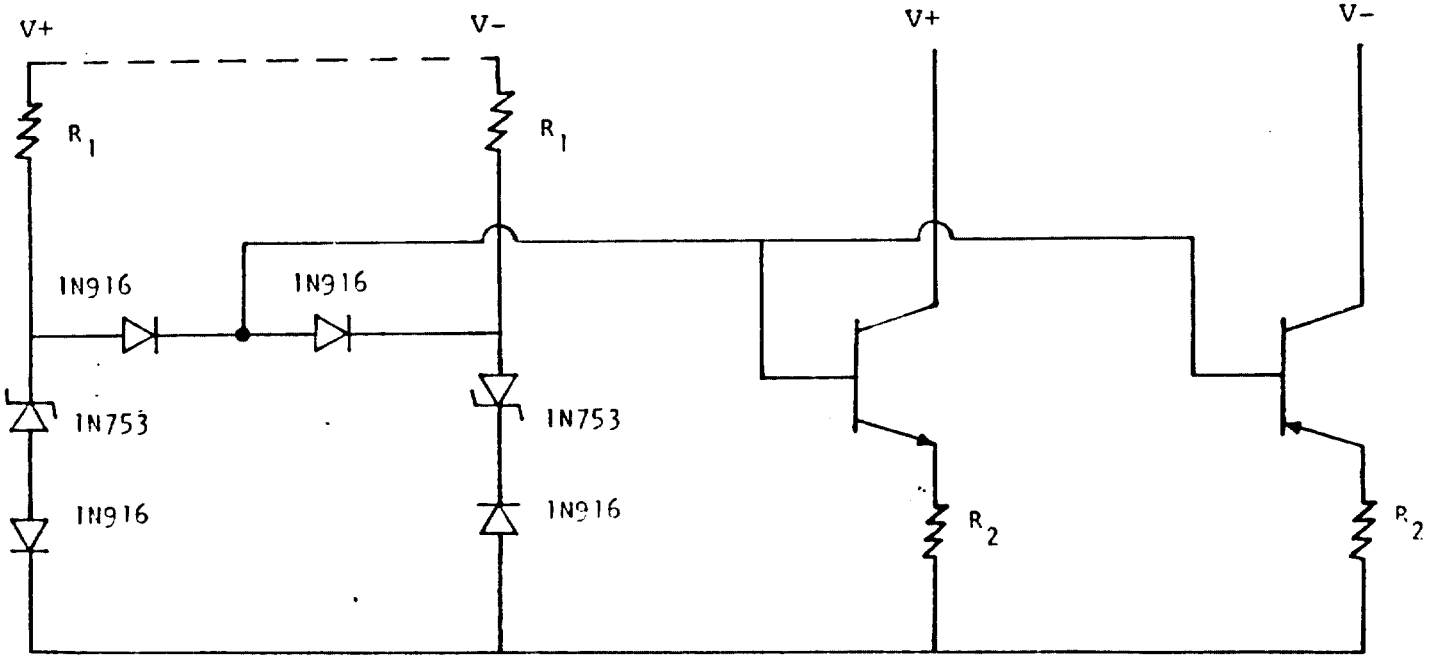
$$E = \left[\ell n \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^{\circ}\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{eV}$$

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

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

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

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



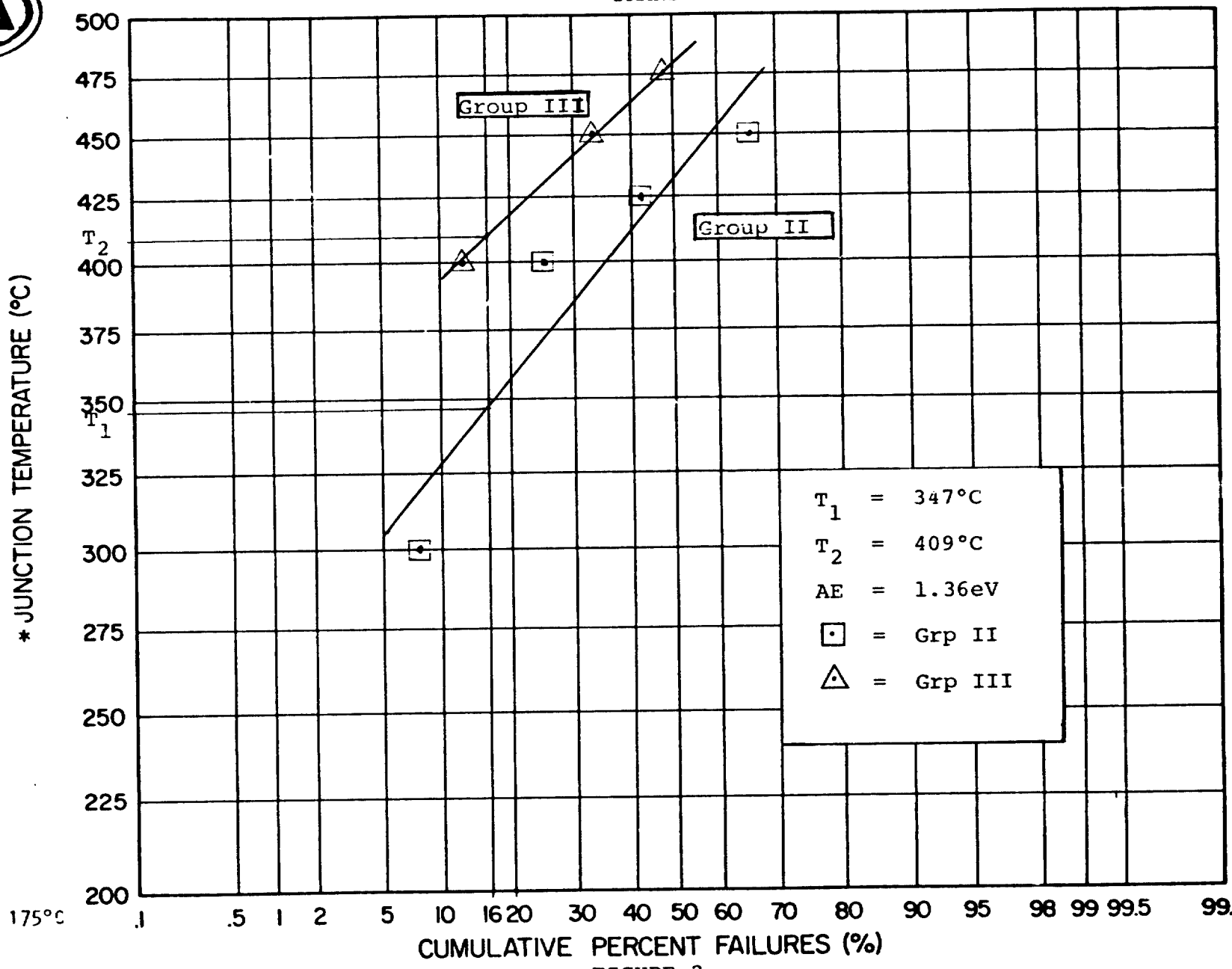
NOTES: R_1 = 800±5%, 2W. R_2 = Individual Part Type Calculation $R_2 = 5.2V/I_E \pm 5\%$, = R_2 = 113 Ω ± 1%, 1/2W

V+ for NPN Transistors
V- for PNP Transistors

FIGURE 1

Power/Temperature Stress Circuit

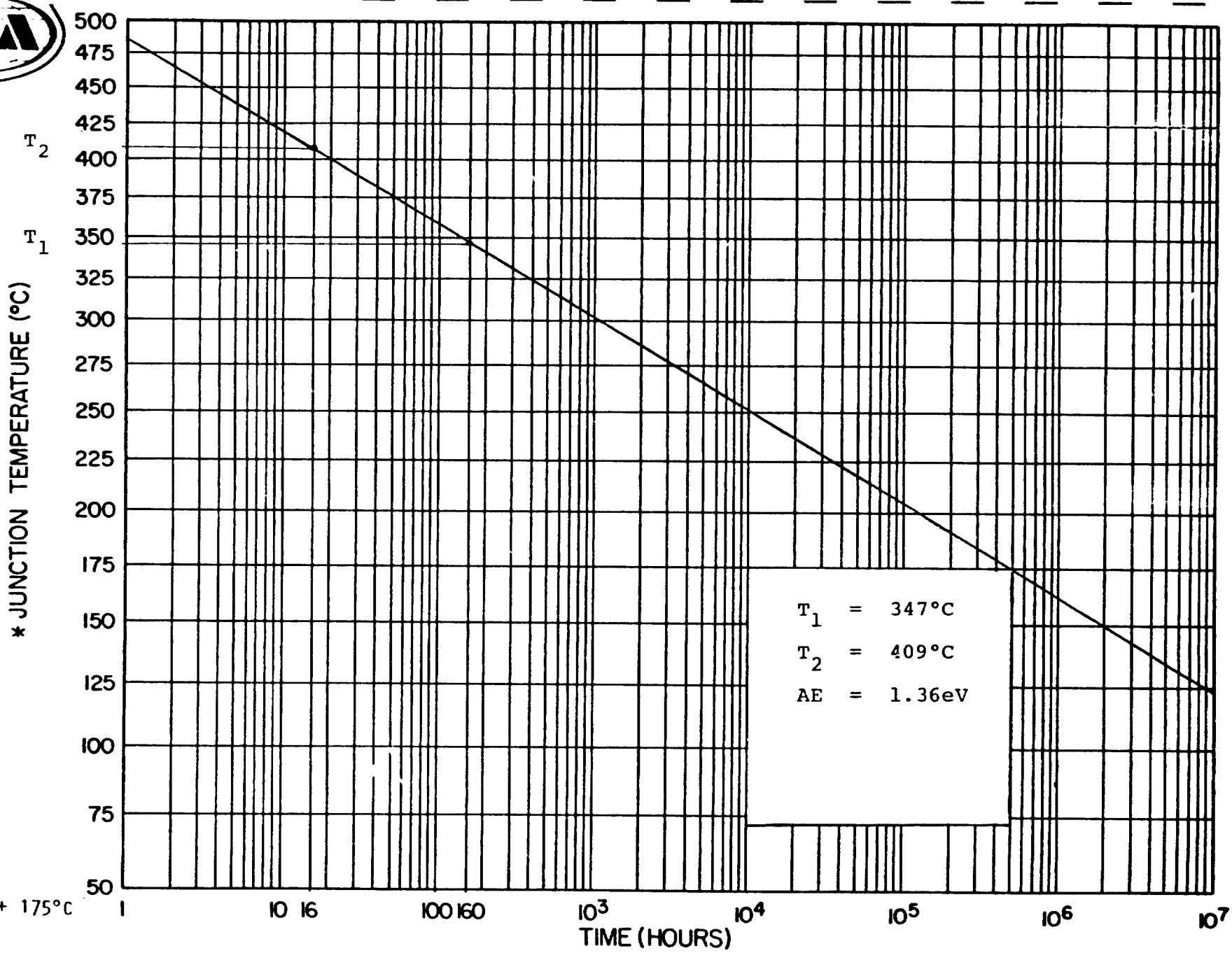
for JANTX2N3637



*NOTE

$T_J \approx T_A + 175°C$

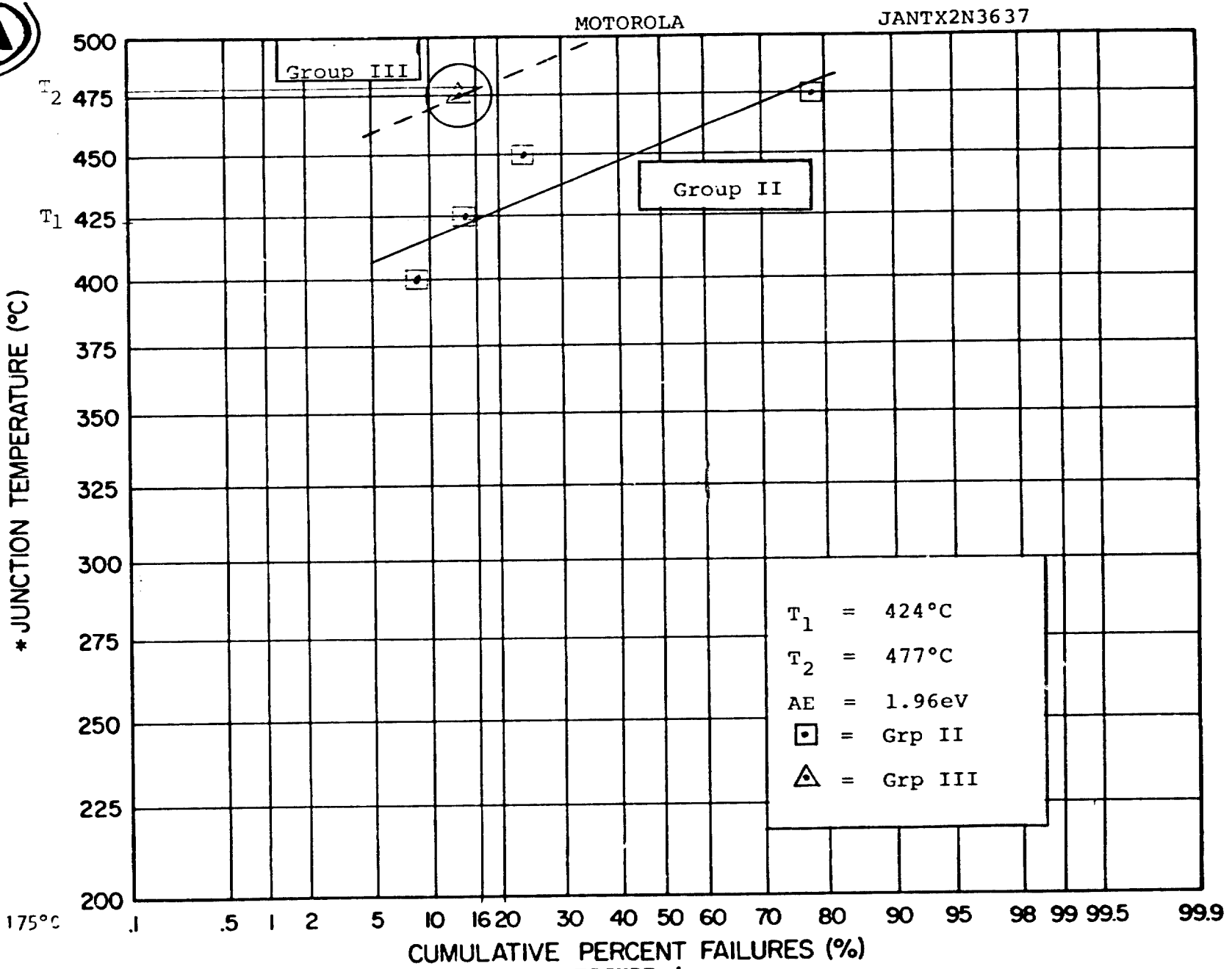
FIGURE 2
Cumulative Percent Failures Versus Junction Temperature, Transitron



*NOTE

$T_J \approx T_A + 175°C$

FIGURE 3
Time Steps Versus Junction Temperature, Transitron

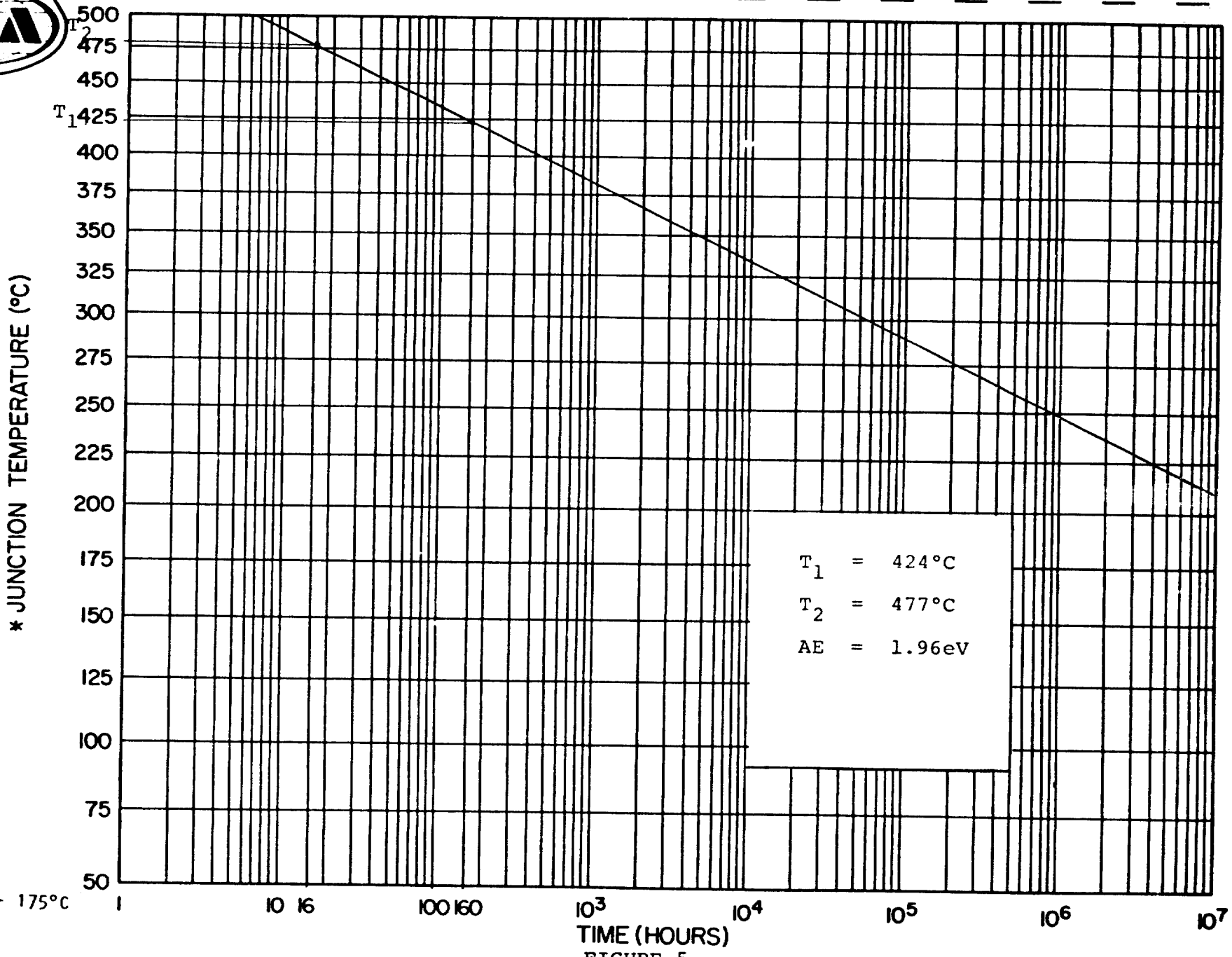


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, Motorola



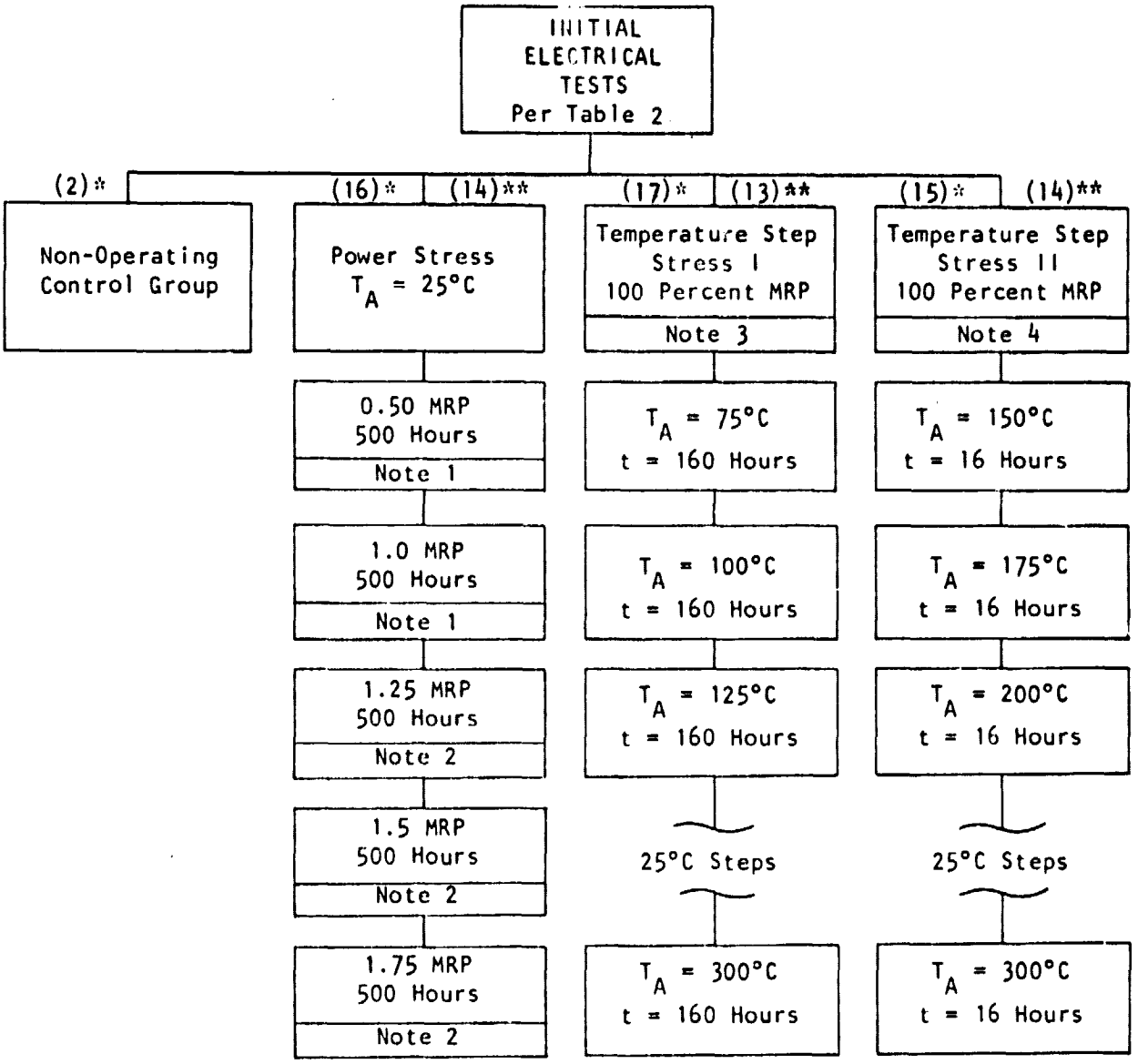
*NOTE

$T_J \approx T_A + 175°C$

FIGURE 5

Time Steps Versus Junction Temperature, Motorola

TABLE 1
TEST FLOW DIAGRAM



Quantity per manufacturer (Transitron*)
(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.

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TABLE 2

PARAMETERS AND TEST CONDITIONS

		SPEC LIMITS*		CAT. LIMITS		
PARAMETER	CONDITIONS	MIN	MAX	MIN	MAX	UNITS
I_{CBO}	V_{CB}=-100V		-.1		- 10	µA
$V_{CE(SAT)1}$	I_C=-10mA I_B=-1mA		-.3		-.45	V
$V_{CE(SAT)2}$	I_C=-50mA I_B=-5mA		-.6		-.9	V
h_{FE}	V_{CE}=-10V I_C=-.1mA	55	900	27.5	1350	-

NOTES:
*In addition, any open or short shall be considered catastrophic

TABLE 3

POWER STRESS BURN-IN CONDITIONS

I_E=50mA	
V_{CE}	%P_D
10V	50
20V	100
25V	125
30V	150
35V	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 has 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}=-.1μA(MAX)		$V_{CE(SAT)1}$=.3V(MAX)		$V_{CE(SAT)2}$=.6V(MAX)		h_{FE}=55(MIN),900(MAX)	
CONDITIONS AND LIMIT	V_{CB}=-100V		I_C=-10mA I_B=-1mA		I_C=-50mA I_B=-5mA		V_{CE}=-10V I_C=-.1mA	
IDENTIFICATION	TRN	MOT	TRN	MOT	TRN	MOT	TRN	MOT
INITIAL DATA								
MIN VALUE	470.00pA	1.660nA	67.00mV	78.00mV	107.0mV	110.0mV	66.60	76.00
MAX VALUE	33.90nA	13.80nA	132.0mV	115.0mV	229.0mV	172.0mV	154.0	144.0
MEAN	3.494nA	3.394nA	88.88mV	98.71mV	142.2mV	139.3mV	112.1	93.57
STD DEV	7.895nA	2.922nA	32.36mV	10.71mV	32.36mV	17.51mV	28.92	19.01
INTERIM DATA								
POWER 50 TO 125% Δ MEAN VALUE								
50% POWER								
50 Hours	-663.0pA	-73.00pA	-0.130mV	-0.140mV	-0.100mV	-0.300mV	3.600	-1.300
150 Hours	-522.0pA	139.0pA	-0.690mV	-0.350mV	-5.000mV	-2.200mV	8.300	0.770
250 Hours	-813.0pA	-251.0pA	-1.820mV	-0.850mV	-6.300mV	-2.200mV	2.800	-2.160
500 Hours	-1.092nA	-635.0pA	-1.820mV	-0.780mV	-5.900mV	-2.600mV	5.100	-1.160
100% POWER								
550 Hours	-645.0pA	-900.0pA	-1.130mV	-0.500mV	-5.300mV	-2.000mV	11.40	0.090
650 Hours	1.918nA	-359.0pA	-83.47mV	-0.920mV	-6.300mV	-2.700mV	12.40	0.770
750 Hours	5.985nA	-128.0pA	-1.500mV	-0.640mV	-6.300mV	-2.700mV	14.30	1.010
1000 Hours	36.10nA	17.00pA	0.180mV	-1.420mV	-11.10mV	-4.700mV	26.70	2.260
125% POWER								
1010 Hours	66.33nA	-21.00pA	-3.250mV	-1.500mV	-10.30mV	-4.500mV	61.90	1.680
1025 Hours	110.0nA	94.00pA	-2.440mV	-1.420mV	-8.900mV	-4.700mV	79.10	1.100
1050 Hours	173.9nA	-39.00pA	-2.630mV	-1.350mV	-9.000mV	-4.800mV	78.00	1.840
1150 Hours	*648.8nA	-70.00pA	-3.720mV	-2.420mV	-9.800mV	-4.600mV	75.70	-0.250
1250 Hours	72.73nA	-151.0pA	-6.020mV	-2.170mV	-13.30mV	-4.300mV	75.50	-0.860
1500 Hours	*1.537mA	358.0pA	*4.554V	*805.5V	*4.542V	*701.8mV	*382.3	*-3.690

(continued on second sheet)

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TABLE 4 (Cont'd)
GROUP I – POWER STRESS DATA SUMMARY

(continued from first sheet)

PARAMETER	I_{CBO}=-.1μA(MAX)		$V_{CE(SAT)1}$=.3V(MAX)		$V_{CE(SAT)2}$=.6V(MAX)		h_{FE}=55(MIN),900(MAX)	
CONDITIONS AND LIMITS	V_{CB}=-100V		I_C=-10mA I_B=-1mA		I_C=-50mA I_B=-5mA		V_{CE}=-10V I_C=-.1mA	
IDENTIFICATION	TRN	MOT	TRN	MOT	TRN	MOT	TRN	MOT
INITIAL DATA								
MIN VALUE	470.0pA	1.660nA	67.00mV	78.00mV	107.0mV	110.0mV	66.60	76.00
MAX VALUE	33.90nA	13.80nA	132.0mV	115.0mV	229.0mV	172.0mV	154.0	144.0
MEAN	3.494nA	3.394nA	88.88mV	98.71mV	142.2mV	139.3mV	112.1	93.57
STD DEV	7.895nA	2.922nA	32.36mV	10.71mV	32.36mV	17.51mV	28.92	19.01
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 Hours	Job Stopped	-855.0pA	Job Stopped	0.750mV	Job Stopped	1.200mV	Job Stopped	1.980
1525 Hours		995.0pA		0.440mV		-1.100mV		1.550
1550 Hours		*7.685mA		-6.250mV		-7.500mV		73.23
1650 Hours		4.836nA		0.54mV		-1.300mV		5.150
1750 Hours		4.957nA		0.450mV		-1.900mV		4.660
2000 Hours		7.356nA		0.530mV		-2.000mV		4.040
175% POWER								
2010 Hours		14.26nA		-0.540mV		-2.500mV		2.970
2025 Hours		7.606nA		-0.460mV		-2.400mV		2.110
2050 Hours		6.536nA		-0.630mV		-1.900mV		3.690
2150 Hours		16.14nA		0.450mV		-1.700mV		0.970
2250 Hours		14.91nA		0.290mV		-2.400mV		1.030
2500 Hours		*8.325mA		*824.5mV		*819.0mV		*-8.580
FINAL DATA								
MIN VALUE	800.0pA	1.950nA	6.000mV	78.00mV	29.00mV	105.0mV	0.000	0.000
MAX VALUE	9.990mA	9.90mA	9.990V	9.990V	9.990V	9.990V	999.0	141.0
MEAN	1.537mA	8.325mA	4.643V	923.2mV	4.684V	958.3mV	494.4	84.99
STD DEV	3.604mA	27.61mA	4.950V	2.734V	4.912V	2.723V	470.0	31.36

* NOTE: Catastrophic Rejects removed from data.

TABLE 5

GROUP I TEMP STRESS I DATA SUMMARY (160 Hours)

PARAMETERS	I_{CBO}=-.1μA(MAX)		$V_{CE(SAT)1}$=.3V(MAX)		$V_{CE(SAT)2}$=.6V(MAX)		h_{FE}=55(MIN),900(MAX)	
CONDITIONS AND LIMITS	V_{CB}=-100V		I_C=-10mA I_B=-1mA		I_C=-50mA I_B=-5mA		V_{CE}=-10V I_C=-.1mA	
IDENTIFICATION	TRN	MOT	TRN	MOT	TRN	MOT	TRN	MOT
INITIAL DATA								
MIN VALUE	500.0pA	1.920nA	66.00mV	90.00mV	105.0mV	126.0mV	82.90	75.10
MAX VALUE	4.590nA	4.000nA	123.0mV	116.0mV	347.0mV	177.0mV	177.0	110.0
MEAN	1.168nA	2.531nA	92.47mV	102.2mV	158.0mV	148.7mV	110.5	93.37
STD DEV	1.089nA	507.7pA	16.63mV	7.420mV	53.16mV	15.22mV	23.08	10.07
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
Total Hours Temp(T_A)								
160 75°C	62.85nA	-323.0pA	-3.590mV	-1.800mV	-9.400mV	-5.600mV	48.70	-0.460
320 100°C	96.00pA	-68.00pA	-1.470mV	-1.200mV	-6.500mV	-3.900mV	-0.400	0.360
480 125°C	63.44nA	-355.0pA	-2.760mV	-1.700mV	-8.600mV	-5.200mV	*48.40	-0.750
640 150°C	-45.00pA	-349.0pA	-2.780mV	-1.400mV	-6.600mV	-4.800mV	-2.400	-0.880
800 175°C	136.0pA	423.0pA	-2.030mV	-0.900mV	-4.600mV	-3.900mV	-1.000	-0.290
960 200°C	-4.000pA	4.564nA	-1.910mV	-0.400mV	-3.000mV	-1.900mV	-13.71	-5.910
1120 225°C	*630.6nA	*769.3nA	*620.5mV	*761.7mV	*386.8mV	*757.5mV	*38.80	-11.69
1280 250°C	*1.350μA	*833.4nA	*669.4mV	12.10mV	*670.5mV	8.600mV	*-46.99	*-15.59
1440 275°C	*2.997μA	1.540nA	*990.5mV	13.30mV	*655.8mV	3.700mV	*159.0	*-19.73
1600 300°C	Job Stopped	*6.136μA	Job Stopped	*4.710V	Job Stopped	*3.358V	Job Stopped	*331.3
FINAL DATA								
FINAL TEMP	275°C	300°C	275°C	300°C	275°C	300°C	275°C	300°C
MIN VALUE	670.0pA	2.580nA	0.000V	73.00mV	0.000V	135.0mV	2.100	0.000
MAX VALUE	9.990μA	9.990μA	9.990V	9.990V	9.999V	9.990V	999.0	999.0
MEAN	2.998μA	6.139μA	1.083V	4.812V	813.8mV	3.507V	269.3	424.7
STD DEV	4.577μA	4.733μA	2.969V	4.756V	1.894V	4.385V	366.3	469.9

*NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA

TABLE 6

GROUP III TEMP STRESS II DATA SUMMARY (16 Hours)

PARAMETERS	I_{CBO}=-.1μA(MAX)		$V_{CE(SAT)1}$=.3V(MAX)		$V_{CE(SAT)2}$=.6V(MAX)		h_{FE}=55(MIN),900(MAX)	
CONDITIONS AND LIMITS	V_{CB}=-100V		I_C=-10mA I_B=-1mA		I_C=-50mA I_B=-5mA		V_{CE}=-10V I_C=-.1mA	
IDENTIFICATION	TRN	MOT	TRN	MOT	TRN	MOT	TRN	MOT
INITIAL DATA								
MIN VALUE	500.0pA	1.370nA	74.00mV	74.00mV	111.0mV	104.0mV	96.00	73.80
MAX VALUE	2.950nA	2.410nA	115.0mV	110.0mV	214.0mV	167.0mV	143.0	120.0
MEAN	1.037nA	1.911nA	88.20mV	96.64mV	143.0mV	140.8mV	114.5	96.84
STD DEV	579.2pA	338.8pA	11.98mV	10.85mV	34.04mV	18.59mV	14.30	15.41
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
Total Hours Temp(T_A)								
16 150°C	237.0pA	373.0pA	0.270mV	-0.350mV	-1.500mV	-2.400mV	6.900	1.870
32 175°C	4.010nA	388.0pA	-0.870mV	0.150mV	-4.500mV	-3.000mV	6.200	3.760
48 200°C	1.102nA	-82.00pA	-0.870mV	-0.280mV	-5.200mV	-3.800mV	7.700	1.800
64 225°C	*99.6nA	1.014nA	19.30mV	0.000mV	*57.30mV	-5.600mV	179.3	2.170
80 250°C	46.45nA	1.118nA	2.070mV	0.360mV	10.10mV	-4.500mV	0.400	1.850
96 275°C	*166.2nA	1.178nA	44.90mV	0.570mV	*141.0mV	-4.700mV	*53.10	0.710
112 300°C	*2.423μA	3.000pA	*1.589V	*2.828V	*2.652V	*2.815V	*-54.93	*-40.11
FINAL DATA								
FINAL TEMP	300°C	300°C	300°C	300°C	300°C	300°C	300°C	300°C
MIN VALUE	460.0pA	170.0pA	85.00mV	80.00mV	124.0mV	107.0mV	0.000	0.000
MAX VALUE	9.990μA	3.050nA	9.990V	9.990V	9.990V	9.990V	118.0	118.0
MEAN	2.424μA	1.914nA	1.677V	2.925V	2.795V	2.956V	59.57	56.73
STD DEV	4.003μA	873.9pA	3.203V	4.468V	3.578V	4.448V	38.86	44.09

*NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA

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			TRN	MOT	TRN	MOT	TRN	MOT
I_{CBO}	-	-.1	μA		* +109.86	* 615.77	* +.56712	* +.77441	* +.40580	* +.00057
$V_{CE(SAT)1}$	-	.3	V		* +.31754	* 62.692	* +.25176	* +.54897	* +.23626	* +.40406
$V_{CE(SAT)2}$	-	.6	V		* +.31746	* +.05596	* +.18604	* +.41025	* +.40703	* +.39871
h_{FE}	55	900	-		* +59.807	* +3.5731	* +25.600	* 27.666	* +28.381	* -3.9929

* NOTE: Catastrophic reject(s) removed from data.

TABLE 8 STEP STRESS CATASTROPHIC FAILURE SUMMARY JAN TX2N3637

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	1	C	0	-
100 hr.	0	-	0	-
250 hr.	2/4 3/2	A/J C/L	1	J
150% 10 hr.	JOB STOPPED		0	-
15 hr.			0	-
25 hr.			1	C
100 hr.			0	-
100 hr.			0	-
250 hr.			0	-
175% 10 hr.			0	-
15 hr.			0	-
25 hr.			0	-
100 hr.			0	-
100 hr.			0	-
250 hr.			1	H

GROUP II 160 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	-	0	-
100° C	0	-	0	-
125°C	1	N	0	-
150°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	2/1	B/F	1	M
250°C	1/1	G/H	1	G
275°C	2/1	C/B/F	1	B
300°C	JOB STOPPED		2/1 2/2	H/I C/F

GROUP III 16 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	2/1 1	C/M E	0	-
250°C	0	-	0	-
275°C	1/1 1	K/C B	0	-
300°C	1/1 1	J/L H	4 1	J B

MFR A - TRANSITRON
MFR B - MOTOROLA

NOTES:

(A) h_{FE}>1300
(B) h_{FE}<275
(C) I_{CBO}>10μA
(D) $V_{CE(SAT)1}$>.45V
(E) $V_{CE(SAT)2}$>.9V
(F) See notes (C), (D) + (E)
(G) See notes (B) + (C)
(H) See notes (B), (C), (D) + (E)
(I) See (D) + (B)
(J) See (B), (D) + (E)
(K) See (B) + (E)
(L) (D) + (E)
(M) SHORTED (VERIFIED BY FAILURE ANALYSIS)
(N) OPEN (VERIFIED BY FAILURE ANALYSIS)

TABLE 9 STEP STRESS PARAMETRIC FAILURE SUMMARY JAN TX2N3637

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	1	B	0	-
250 hr.	1	B	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	-	0	-
150% 10 hr.	Job Stopped		0	-
15 hr.	↓	↓	0	-
25 hr.			0	-
100 hr.			0	-
100 hr.			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	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	1	C	0	-
100° C	0	-	0	-
125 °C	0	-	0	-
150 °C	0	-	0	-
175 °C	0	-	0	-
200 °C	2	A	0	-
225 °C	0	-	0	-
250 °C	2	A	0	-
275 °C	0	-	0	-
300 °C	Job Stopped		0	-

GROUP III 16 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150 °C	0	-	0	-
175 °C	0	-	0	-
200 °C	0	-	0	-
225 °C	0	-	0	-
250 °C	1	C	0	-
275 °C	0	-	0	-
300 °C	1	B	0	-

MFR A = TRANSITRON

MFR B = MOTOROLA

NOTES:

(A) h_{FE} minimum limit failure

(B) I_{CBO} limit failure

(C) $-h_{FE}$ minimum and I_{CBO} limits failure

APPENDIX A

FAILURE ANALYSIS

Power Stress

JANTX2N3637

MFS STEP-STRESS TEST

FAILURE ANALYSIS-TRANSISTORS

(POWER STRESS)

Date 9 January 1979

/N 2CN242-07A P/N 2N3637 (PNP) MFR: Transitron

/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -uA- @V_{CB}= 100 V (Cat.Lim. 10uA)	BV_{EBO} -volts-	h_{FE} @ I_C= 100uA; V_{CE} = 10 V. (Cat.Lim. 27.5-1350)	V_{BEO} -volts- @ I_{BEO}= 10mA	INITIAL REJ. @ test sequence #:	INITIAL REJ. FOR:
1787	short	7.5	∞	7.5	none	0.72	27 (125% MRP 1250 Hrs.)	I_{CBO}
1796	open	short	short	open	none	open	29 (125% MRP 1500 Hrs.)	I_{CBO}
1801	open	7.1	∞	open	none	open	29 (125% MRP 1500 Hrs.)	I_{CBO}

NTERNAL VISUAL INSPECTION

S/N 1787 has a small damaged spot on the emitter-base junction. (see Figure A-1).

S/N 1796 and 1801 have fused internal emitter wires which are open, and metallization melting at the emitter wire die bond (see Figure 2). S/N 1801 has a different layout geometry which introduces "field plates" over the base-emitter junction. (See Figures -2 and A-3.)

ONCLUSION

These Transitron samples failed due to excessive collector-to-emitter current to which hey were subjected in the power step-stress series. There is no evidence that any device fault or high voltage transient contributed to their failure.

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*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

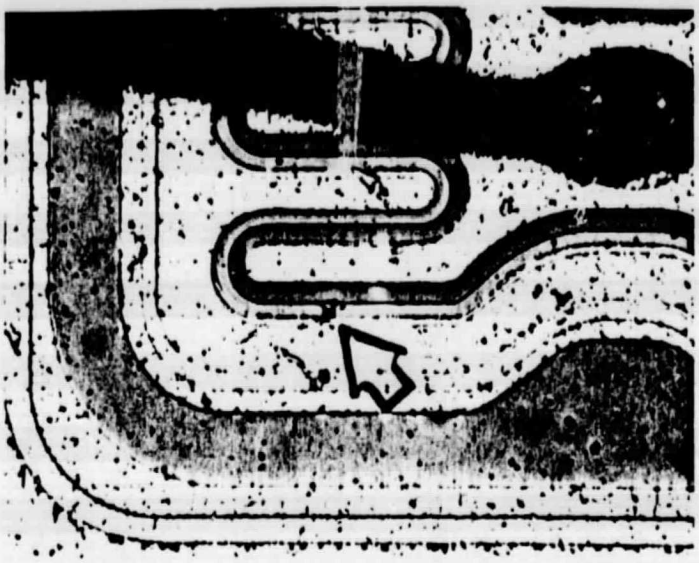

FIGURE A-1
S/N 1787, Transitron Sample Showing
Emmitter-Base Junction Damage, 280X.

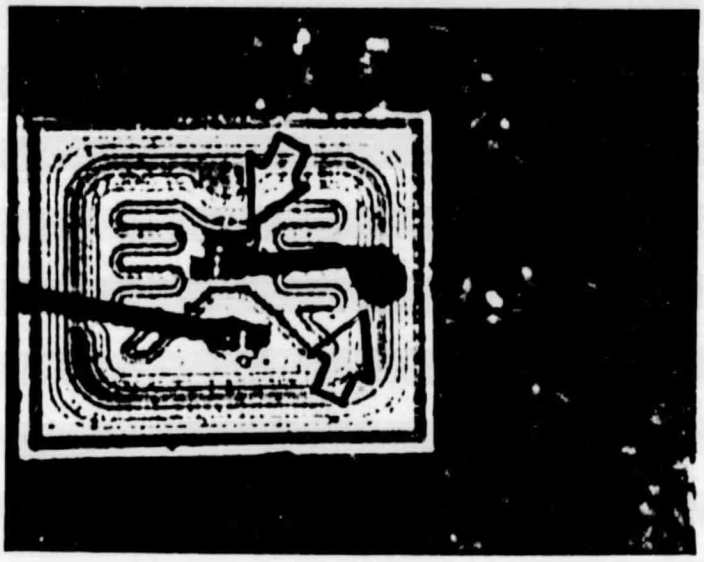

FIGURE A-2
S/N 1796, Transitron Sample Showing Fused
End of Wire Lead and Emitter Metallization
Damage, 80X.

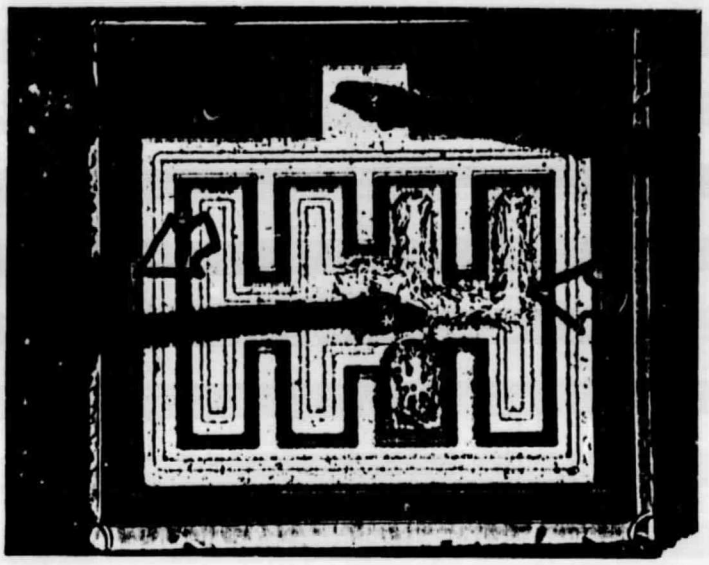

FIGURE A-3
S/N 1801, Transitron Sample Showing Fused End of Wire Lead, and Melted Emitter Metallization, 100X. This sample has an improved geometry. (Field Plates)

APPENDIX B

FAILURE ANALYSIS

Temperature Stress I

MSFC STEP-STRESS TEST

FAILURE ANALYSIS - TRANSISTORS
(160 Hours)

Date 9 January 1979

/N 2CN242-07B P/N 2N3637 (PNP) MFR Transitron

/N	BV_{CEO} -volts Cat.Lim. 10uA	BV_{CBO} volts	I_{CBO} -μA @V_{CB} = 100V.	BV_{EBO} -volts	h_{FE} @I_C = 100μA; V_{CE} = 10V. Cat Lim. 27.5-1350	V_{BEO} -volts @I_{BEO} = 10 mA	INITIAL REJ. @ test sequence #:	INITIAL REJ. FOR:
1810	160	open	open	open	none	open	07 (125°C 480 Hrs.)	I_{CBO}
	(Inv)							
1817	1.2(S)	10(R)		7.6	*	0.82	15 (225°C 1120 Hrs.)	I_{CBO}
1818	13.6	18.5		7.6	86	0.71	19 (275°C 1440 Hrs.)	I_{CBO}
		(R)						
	*Cannot meet test conditions due to high leakage.							

INTERNAL VISUAL INSPECTION

S/N 1810 - This sample has a newer die geometry than the other two Transitron samples of this lot. The internal base wire is fused and open (see Figure B-1).

S/N 1817 & 1818 - has darkened emitter metallization and electromigrated emitter metallization (see Figures B-2 and B-3).

OR
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*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

MSFC STEP-STRESS TEST

FAILURE ANALYSIS-TRANSISTORS

(160 Hrs.)

Date 9 January 1979

/N 2CN242-07B P/N 2N3637 (PNP) MFR: Motorola

S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -uA- @V_{CB}= 100 V	BV_{EBO} -volts-	h_{FE} @ I_C= 100uA; V_{CE} = 10 V.	V_{BEO} -volts- @ I_{BEO}= 10 mA	INITIAL REJ.@ test sequence #:	INITIAL REJ. FOR
	Cat.Lim. 10μA				Cat.Lim. 27.5-1350			
354	15	45(S)	180	6.2	0.35	0.73	17 (250°C 1280 Hrs.)	I_{CBO}
1876	0.4(R	2.1(S)	∞	2.0(S)	none	0.71	21 (300°C 1600 Hrs.)	I_{CBO}
382	open	short	∞	open	none	open	15 (225°C 1120 Hrs.)	I_{CBO}

NTERNAL VISUAL INSPECTION

All these Motorola samples have evidence of melted aluminum metallization over the emitter area. In addition S/N 1882 has a fused internal wire lead (see Figures B-4 and -5).

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

**h_{FE} trace very leaky.

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

CONCLUSIONS

All of these samples failed because of excess emitter-to-collector current acting over a relatively long time, and initiated by thermal runaway under the high ambient temperatures of the thermal step stress test.

There is a mixture of layout designs among the Transitron parts in which the rectangular layout is superior to the "butterfly" pattern because it employs "field plate" extension of the emitter metallization over the base-emitter junction. This is intended to reduce the tendency of P-channel transistors toward surface inversion.

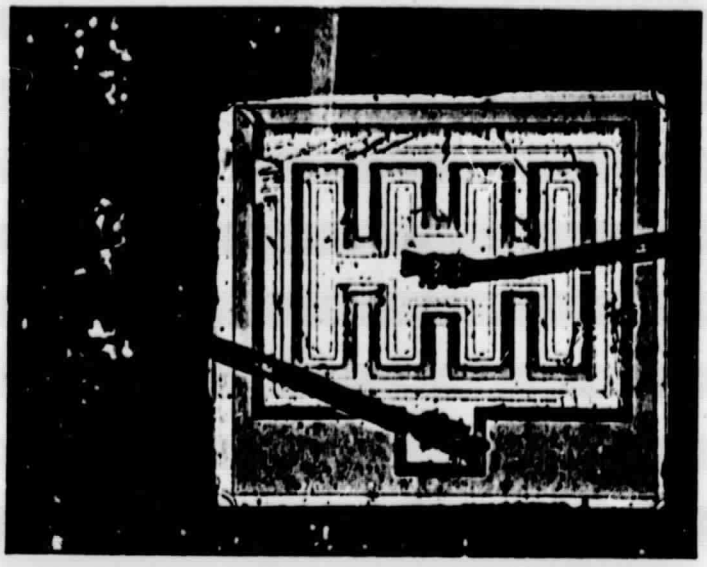

FIGURE B-1
S/N 1810, Transitron Transistor Showing New Die Geometry, 80X. Arrow indicates fused end of emitter wire.

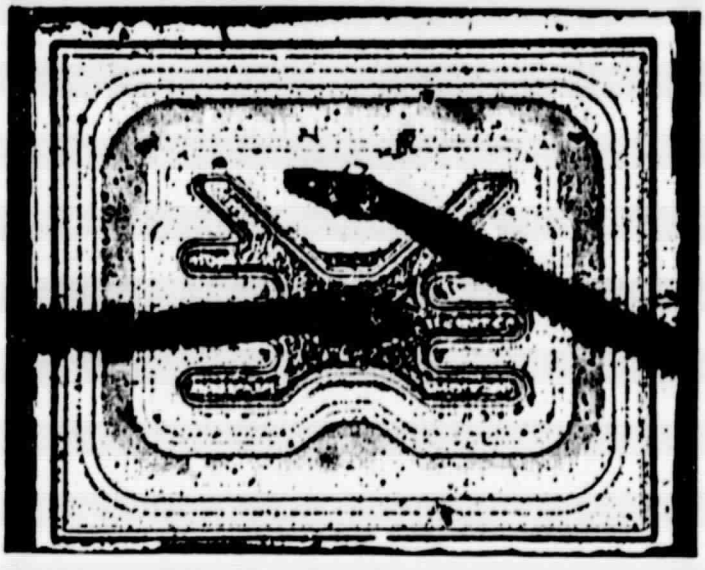

FIGURE B-2
S/N 1817, Transitron Transistor Showing "Butterfly" Pattern, 124X. The emitter metallization is darkened due to over-heating.

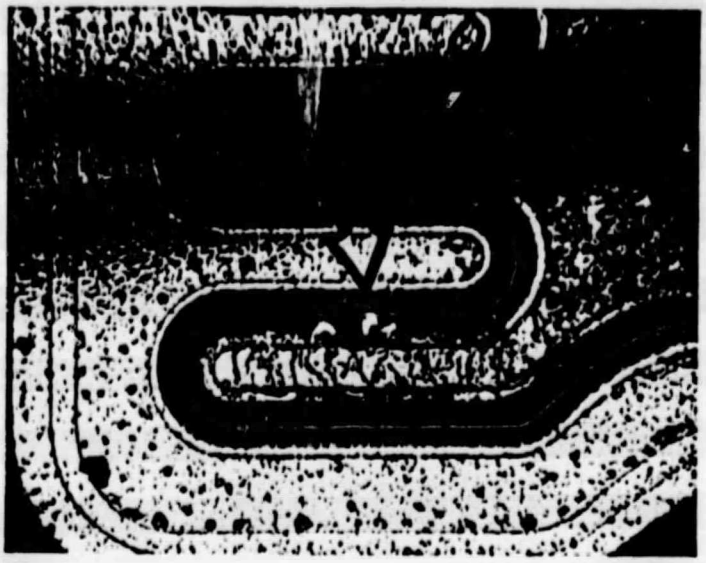

FIGURE B-3
S/N 1817, Transitron Transistor, 400X. The arrow points to electromigrated aluminum which reaches the emitter-base junction.

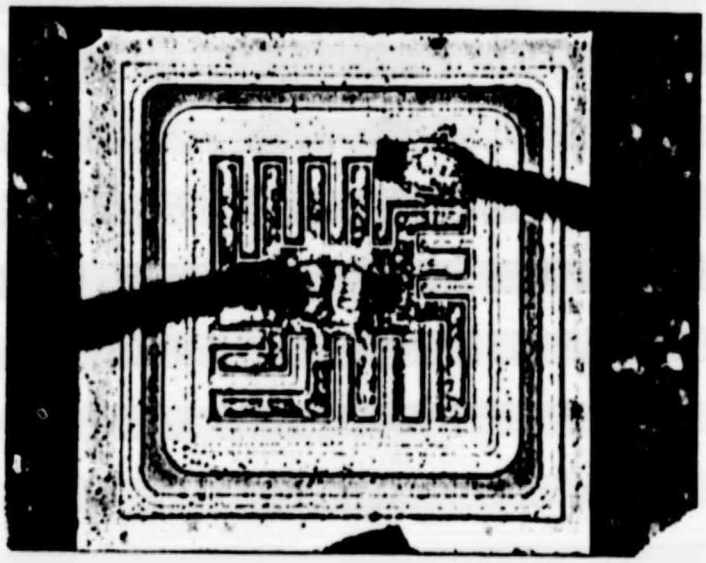

FIGURE B-4
S/N 1876, Motorola Transistor, 132X.
The emitter metallization has been melted.

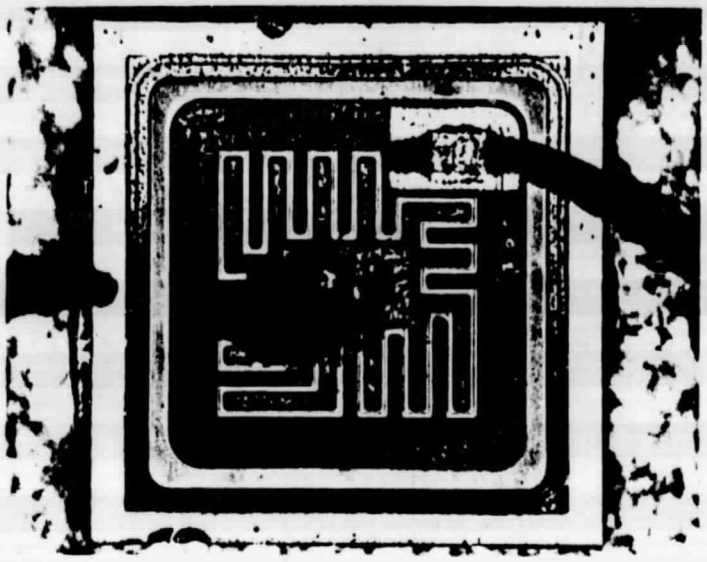

FIGURE B-5
S/N 1882, Motorola Transistor, 132X. The die is blackened by lead wire material which evaporated when the wire fused. Note melted ball of aluminum on die.

APPENDIX C

FAILURE ANALYSIS

Temperature Stress II

MSFC STEP-STRESS TEST

FAILURE ANALYSIS-TRANSISTORS

(16 Hrs.)

Date 9 January 1979

J/N 2CN242-07C P/N 2N3637 (PNP) MFR: Transitron

S/N	BV_{CEO} -volts- Cat.Lim. 10uA	BV_{CBO} -volts-	I_{CBO} -uA- @V_{CB}= 100 V.	BV_{EBO} -volts-	h_{FE} @ I_C = 100uA; V_{CE} 10 V. Cat.Lim. 27.5-1350	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ.@ test sequence #:	INITIAL REJ. FOR:
1828	0.9(R)	72(R)	200(R)	7.3	low*(R)	0.72	09 (225°C 64 Hrs.)	I_{CBO}
opened:	120 (Inv)	120 (Inv)	40µA					
	(R)	(R)						
1829	short	7.4(R)	∞	7.4(R)	low*(R)	0.72	09 (225°C 64 Hrs.)	I_{CBO}
1832	6.7(R)	20.5	900µA	7.3	none	0.71	15 (300°C 112 Hrs.)	I_{CBO}
		(R)						

*Can't meet h_{FE} test conditions due to high leakage and low BV_{CEO}.

INTERNAL VISUAL INSPECTION

No significant visual defects appeared on these devices except for a slight darkening of the emitter metallization on S/N 1832 (see Figure C-1). The aluminium was stripped off S/N 1829 to further search for possible visual defects in the lower layers but none were found.

CONCLUSION

These Transitron samples failed from an excess of collector-to-emitter current which damaged the diffused junctions within the bulk of the silicon. There is also surface leakage which is not unusual in semiconductor devices which have experienced destructive extremes of temperature. (continued)

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

*h_{FE} trace very leaky.

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

CONCLUSIONS (Continued)

The Transitron samples have two different geometries and Motorola consists of a third type (see Figures C-1 through C-3). The Transitron "A" geometry does not provide a field plate over the base-collector junction of this PNP device. In this respect it is a poorer design than the other two layouts for long-term reliability. The Motorola chip appears to have a longer emitter periphery than either Transitron part, which again is a superior design for minimizing h_{FE} fall-off with increasing collector current and for reducing the emitter current density. These design superiorities were borne out in the electrical tests which showed all the Motorola samples to be acceptable when the samples were received for analysis, while Transitron S/N 1828, 1829, and 1832 had degraded catastrophically. The recovery of all the Motorola parts is due to their return to equilibrium following the formation of temporary static charges which caused their initial rejection after burn-in.

MSFC STEP-STRESS TEST

FAILURE ANALYSIS-TRANSISTORS

(16 Hrs.)

Date 9 January 1979

I/N 2CN242-07C P/N 2N3637 (PNP) MFR: Motorola

			Max.= 100nA		Min.= 55			
S/N	BV_{CEO} -volts-	BV_{CBO} -volts-	I_{CBO} -uA- @V_{CB}= 100 V	BV_{EBO} -volts-	h_{FE} @ I_C = 100uA; V_{CE} = 10 V.	V_{BEO} -volts- @ I_{BEO} = 10 mA	INITIAL REJ.@ test sequence #:	INITIAL REJ. FOR:
857	180 H	220	0.2	6.2	61	0.7	15	CAT
1858	200 H	225	0.2	6.2	64	0.7	15	CAT
883	210 H	230	0.2	6.2	68	0.7	15	CAT

INTERNAL VISUAL INSPECTION:

No significant anomolies were seen on any of the above samples. (See Figure C-3.)

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

**h_{FE} trace very leaky.

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

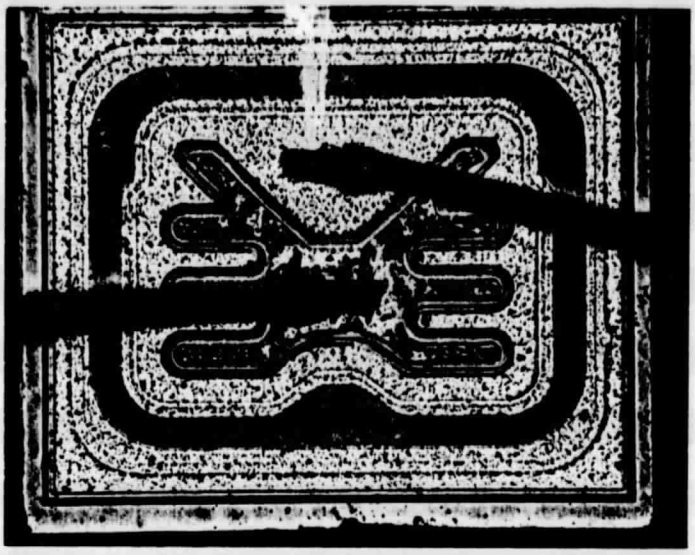

FIGURE C-1
S/N 1832, Transitron Transistor "A" Geometry, 124X. The emitter metallization is darkened due to slight melting.

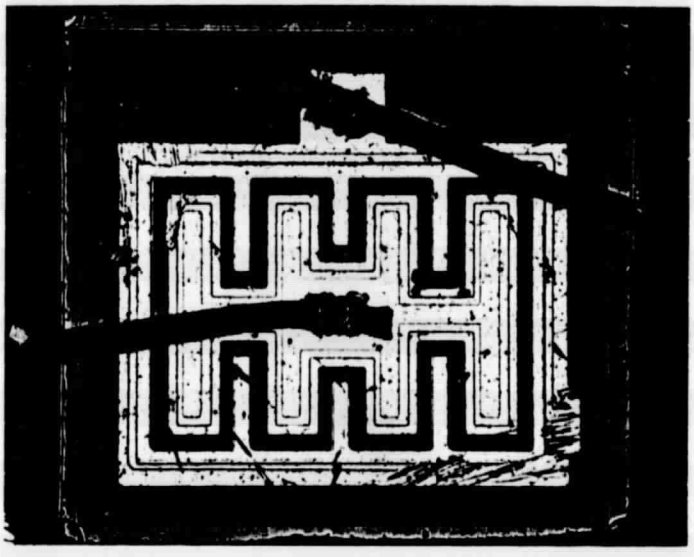

FIGURE C-2
Transitron "B" Geometry, 104X.

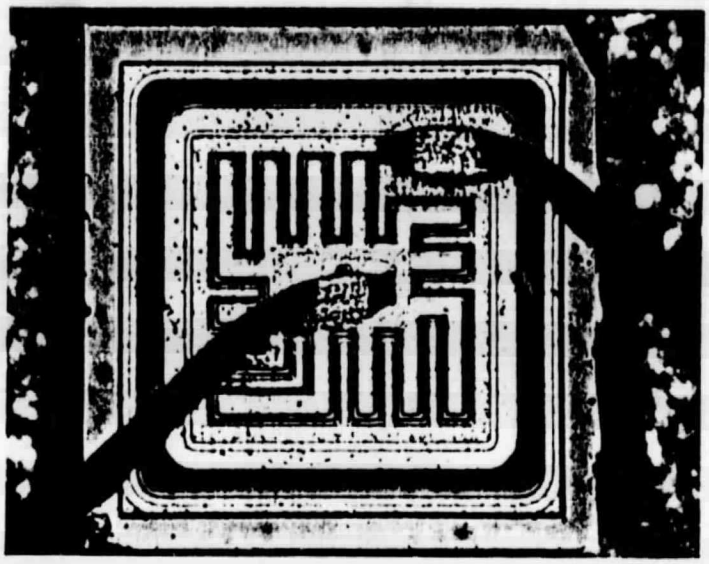

FIGURE C-3
S/N 1857, Typical Motorola Geometry, 128X.