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Produced by the NASA Center for Aerospace Information (CASI)
TRANSISTOR
STEP STRESS TESTING PROGRAM

MSFC/NASA CONTRACT NUMBER
NAS8-31944

FINAL REPORT
FOR
JANTX 2N2945A

JANUARY 1979

Prepared
For

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

DCA RELIABILITY LABORATORY
SPECIAL PRODUCTS DIVISION
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SUNNYVALE, CALIFORNIA 94086
FOREWORD

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

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 JANTX2N2945A manufactured by Raytheon and Teledyne.

A total of 48 samples from each manufacturer were divided equally (16 per group) into three groups and submitted to the processes outlined in Table I. In addition, two control 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 II after the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 High-Speed Computer-Controlled Test System. In addition, some bench testing was required on the devices.

2.2 Stress Circuit

The test circuit in Figure 1 was used to power all of the test devices during the power/temperature stress conditions. The $V_{CE}$ was varied so that at least one of the devices was subjected to maximum rated power (MRP). All the remaining devices were subjected to no less than 90 percent 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 transistors were stressed in 500-hour steps at 50, 100, 125, 150 and 175 percent MRP for a total of 2500 hours or until 50 percent 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 I.

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 a total of 1600 hours of stress at MRP 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 percent 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 I.

2.5 Group III - Temperature Stress II
Thirty units, 16 from Teledyne and 14 from Raytheon, were submitted to the Temperature Stress II process. Group III was subjected to a total of 112 hours of stress at MRP 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 percent or more of the devices in a sample lot failed*. Electrical measurements were

*Conditions for failure:
A) Open or short
B) Leakage exceeds the MIL limit by 100 times
C) Other parameters exceed MIL limits by 50 percent or more
performed on all specified electrical parameters after each temperature step. See Table I.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I – Power Stress

3.1.1 Raytheon. The Raytheon sample lot completed the entire 2500-hour Group I testing with no catastrophic failures. Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{CBO}$ changed 12.5pA from an initial mean of 69.37pA to a final mean of 56.87pA.

2) The mean value for $h_{FE}$ changed 8.3 from an initial mean of 155.6 to a final mean of 147.3.

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

3.1.2 Teledyne. The Teledyne sample lot completed the entire 2500-hour Group I testing with no catastrophic failures. Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{CBO}$ changed 69.26pA from an initial mean of 153.5pA to a final mean of 84.24pA.

2) The mean value for $h_{FE}$ changed 69.26 from an initial mean of 153.5 to a final mean of 84.24.

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

3.1.3 Statistical Summary – Group I. Table IV outlines the results of Group I – Power Stress process for the two electrical parameters and measurement points for both Raytheon and Teledyne.
3.2 Group II - Temperature Stress I

3.2.1 Raytheon. The Raytheon sample lot completed a total of 1440 hours before the lot was stopped because of a failure rate that reached 50 percent of the lot. The first failure occurred 160 hours into the +250°C temperature step. Serial Number 4432 failed the minimum $h_{FE}$ limit. The last seven failures occurred 160 hours into the +275°C temperature step. Serial Numbers 4423, 4424, 4426, 4431, 4436, 4437 and 4438 failed the minimum $h_{FE}$ limit. Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{CBO}$ changed 362.25pA from an initial mean of 73.75pA to a final mean of 436.0pA.

2) The mean value for $h_{FE}$ changed 81.43 from an initial mean of 134.9 to a final mean of 53.47.

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

3.2.2 Teledyne. The Teledyne sample lot completed the entire Group II testing with a total of nine catastrophic failures. The first failure occurred 160 hours into the +200°C temperature step. Serial Number 4476 failed the minimum $h_{FE}$ limit. The next failure occurred 160 hours into the +275°C temperature step. Serial Number 4475 failed because of excessive $I_{CBO}$ leakage. The last seven failures occurred 160 hours into the +300°C temperature step. Serial Numbers 4477, 4480, 4482, 4485, 4487, 4488, and 4489 failed because of excessive $I_{CBO}$ leakage.

Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{CBO}$ changed 551.61nA from an initial mean of 86.87pA to a final mean of 551.7nA.
2) The mean value for $h_{FE}$ changed 12.2 from an initial mean of 159.9 to a final mean of 147.7.

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

3.2.3 Statistical Summary — Group II. Table V of this report outlines the results of Group II — Temperature Stress I testing for the two electrical parameters and all of the measurement points pertaining to both Raytheon and Teledyne.

3.3 GROUP III — Temperature Stress II

3.3.1 Raytheon. The Raytheon sample lot completed the entire 112-hour Group III testing with a total of one catastrophic failure. Two failures had occurred before the actual step stress started. Serial Numbers 4444 and 4445 failed the minimum $h_{FE}$ limit. The one testing failure occurred 16 hours into the +300°C temperature step. Serial Number 4449 failed the minimum $h_{FE}$ limit. Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{CBO}$ changed 13.04pA from an initial mean of 67.33pA to a final mean of 54.29pA.

2) The mean value for $h_{FE}$ changed 45.1 from an initial mean of 160.2 to a final mean of 115.1.

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

3.3.2 Teledyne. The Teledyne sample lot completed the entire 112-hour Group III testing with a total of two catastrophic failures. The two failures occurred 16 hours into the +275°C temperature step. Serial Numbers 5682 and 5692 failed because of excessive $I_{CBO}$ leakage.
Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{CBO}$ changed 367.61pA from an initial mean of 65.29pA to a final mean of 432.9pA.

2) The mean value for $h_{FE}$ changed 15.0 from an initial mean of 146.9 to a final mean of 131.9.

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

3.3.3 Statistical Summary - Group III. Table VI outlines results for Group III - Temperature Stress II testing for the two electrical parameters specified for this job. Results are recorded at each measurement point for both Raytheon and Teledyne.

4.0 FINAL DATA SUMMARY

Table VII 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 VIII and IX summarize the failures encountered for all three stress groups. The failures are separated into two categories: catastrophic failures in Table VIII and parametric failures in Table IX. The data from Table VIII 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 3 and 5 respectively. Junction temperature is plotted on an inverse hyperbolic scale.
5.0 CONCLUSIONS

The only Step Stress that was detrimental to both manufacturers' sample lots was the Group II - Temperature Stress I testing. The Raytheon sample lot was stopped 160 hours before the completion of the testing because of half the lot failing $h_{FE}$ limits. Failure Analysis shows that the samples for Raytheon have extensive gold-aluminum intermetallic formations. The absence of shorts, opens, and junction leakage suggests that the loss of $h_{FE}$ was caused by a reduction in emitter efficiency.

The Teledyne samples experienced similar contaminations and, although the lot was not stopped, it ended up having more catastrophic failures than the Raytheon lot. The fact that the reject rate in the Group III testing was slight compared to the Group II testing suggests that time was a factor here. Note that the Group III testing has all the high temperatures as Group II, but the devices in the Group II testing are held at these high temperatures 10 times longer than the Group III devices.

A plot showing cumulative failure distribution for Groups II and III testing was done for both Raytheon and Teledyne (Figures 2 and 3, and 4 and 5, respectively). Figures 2 and 3 display the data for Raytheon used to calculate an activation energy of 2.16eV. Figures 4 and 5 display the data for Teledyne used to calculate an activation energy of 2.72eV.

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 drawn using the least square method.
The activation energy was calculated from the formula:

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

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 °C of 16% failure for Group II.
- \( T_2 \) = temperature in °C of 16% failure for Group III.
FIGURE 1
Power/Temperature Stress Circuit

NOTES:
R₁ = 800±5%, 2W  R₂ = 130±18%, 1W
Use V+ for NPN Transistors; Use V- for PNP Transistors.
NOTE
FOR TABLES
4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of $\pm 1\%$ of the reading and $\pm$ one digit except for readings greater than 9.99mA which have an absolute accuracy of $\pm 2\%$ of the reading and $\pm$ 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.
Figure 2
Cumulative Percent Failures Versus Junction Temperature, Raytheon

T1 = 432°C
T2 = 481°C
\[ \triangle = \text{Grp III} \]
\[ \square = \text{Grp II} \]
AE = 2.16eV

*NOTE
\[ T_J \approx T_A + 175°C \]
Cumulative Percent Failures Versus Junction Temperature, Teledyne

**NOTES**

* Data point pertains to both Group II and Group III.

- $T_1 = 421^\circ C$
- $T_2 = 458^\circ C$
- $AE = 2.72eV$

**GROUPS**

- Group II
- Group III

**NOTE**

$T_J \approx T_A + 175^\circ C$
Time Steps Versus Junction Temperature, Teledyne

\[ T_1 = 421°C \]
\[ T_2 = 458°C \]
\[ AE = 2.72eV \]

\[ T_J = T_A + 175°C \]
TABLE I
TEST FLOW DIAGRAM

INITIAL ELECTRICAL TESTS Per Table II

(2) * Non-Operating Control Group

(16) * Power Stress
\( T_A = 25^\circ C \)

- 0.50 MRP
  500 Hours
  Note 1

- 1.0 MRP
  500 Hours
  Note 1

- 1.25 MRP
  500 Hours
  Note 2

- 1.5 MRP
  500 Hours
  Note 2

(16) * Temp Step Stress I
100% MRP

- \( T_A = 75^\circ C \)
  \( t = 160 \) Hours

- \( T_A = 100^\circ C \)
  \( t = 160 \) Hours

- \( T_A = 125^\circ C \)
  \( t = 160 \) Hours

(16) * Temp Step Stress II
100% MRP

- \( T_A = 150^\circ C \)
  \( t = 16 \) Hours

- \( T_A = 175^\circ C \)
  \( t = 16 \) Hours

- \( T_A = 200^\circ C \)
  \( t = 16 \) Hours

(16) * 25°C Steps

- \( T_A = 300^\circ C \)
  \( t = 160 \) Hours

- \( T_A = 300^\circ C \)
  \( t = 16 \) Hours

*Quantity per manufacturer (Raytheon and Teledyne)

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

<table>
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<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>SPECIFICATION LIMIT</th>
<th>CATASTROPHIC LIMIT</th>
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<tr>
<td></td>
<td></td>
<td>MIN</td>
<td>MAX</td>
</tr>
<tr>
<td>$I_{CBO}$</td>
<td>$V_{CB} = -25V, I_{E} = 0$</td>
<td>-0.2</td>
<td></td>
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<tr>
<td>$h_{FE}$</td>
<td>$V_{CE} = -0.5V, I_{C} = -1mA$</td>
<td>70</td>
<td>900</td>
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1. In addition, any open or short shall be considered catastrophic.

### Table III
POWER STRESS BURN-IN CONDITIONS

<table>
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<tr>
<th>$I_E = 43.5mA$</th>
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<tr>
<td>$V_{CE}$</td>
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<tr>
<td>4.6V</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>9.1V</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>11.4V</td>
<td></td>
<td>125</td>
</tr>
<tr>
<td>13.7V</td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>16.0V</td>
<td></td>
<td>175</td>
</tr>
<tr>
<td>PARAMETER</td>
<td>$I_{CBO} = 0.2\text{nA (max)}$</td>
<td>$I_E = 70(\text{min})$ $900(\text{max})$</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>CONDITIONS AND LIMIT</td>
<td>$V_{CB} = -25\text{V}, I_E = 0$</td>
<td>$V_{CE} = -0.5\text{V} &amp; I_C = -1.0\text{mA}$</td>
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<th>TELEDYNE</th>
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<th>TELEDYNE</th>
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<td>MIN VALUE</td>
<td>50.00pA</td>
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<td>105.00</td>
<td>111.00</td>
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<td>MAX VALUE</td>
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<td>MEAN</td>
<td>69.37pA</td>
<td>153.50pA</td>
<td>155.60</td>
<td>153.50</td>
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<tr>
<td>STD DEV</td>
<td>12.98pA</td>
<td>28.98pA</td>
<td>32.32</td>
<td>28.98</td>
</tr>
</tbody>
</table>

| INTERIM DATA   |          |          |          |          |
| POWER 50 TO 125% |        |          |          |          |
| $\Delta$ MEAN VALUE |        |          |          |          |
| 50% POWER      |          |          |          |          |
| 50 hrs         | -16.16pA | -0.3pA   | -0.9     | -0.3     |
| 150 hrs        | -4.37pA  | -1.1pA   | -1.7     | -1.1     |
| 250 hrs        | 1.25pA   | -2.8pA   | -3.7     | -2.8     |
| 500 hrs        | -25.62pA | -2.6pA   | -5.3     | -2.6     |
| 100% POWER     |          |          |          |          |
| 550 hrs        | -28.75pA | -2.0pA   | -1.8     | -2.0     |
| 650 hrs        | -36.87pA | -4.3pA   | -1.0     | -4.3     |
| 750 hrs        | -30.00pA | -5.0pA   | -2.8     | -5.0     |
| 1000 hrs       | -23.12pA | -8.6pA   | -3.7     | -8.6     |
| 125% POWER     |          |          |          |          |
| 1010 hrs       | -18.75pA | -10.2pA  | -3.7     | -10.2    |
| 1025 hrs       | -0.62pA  | -9.2pA   | -2.7     | -9.2     |
| 1050 hrs       | -3.75pA  | -9.2pA   | -2.5     | -9.2     |
| 1150 hrs       | -15.00pA | -13.1pA  | -5.4     | -13.1    |
| 1250 hrs       | -12.50pA | -12.8pA  | -2.7     | -12.8    |
| 1500 hrs       | -6.87pA  | -12.0pA  | -0.5     | -12.0    |

(continued on second sheet)
## TABLE IV (Cont'd)

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<thead>
<tr>
<th>PARAMETER</th>
<th>( I_{CBO} = -0.2\text{nA} )</th>
<th>( h_{FE} = 70\text{(min)})</th>
<th>( 900\text{ (max)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONDITIONS AND LIMITS</td>
<td>( V_{CB} = -25V, I_E = 0 )</td>
<td>( V_{CE} = -0.5V &amp; I_C = 1.0\text{mA} )</td>
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<tr>
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<td>TELEDYNE</td>
<td>RAYTHEON</td>
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<tr>
<td>MIN VALUE</td>
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<td>50.00pA</td>
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</tr>
<tr>
<td>MAX VALUE</td>
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<td>140.00pA</td>
<td>223.00</td>
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<td>69.37pA</td>
<td>153.50pA</td>
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<td>28.98pA</td>
<td>32.32</td>
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<tr>
<td>POWER 150 TO 175%</td>
<td>Δ MEAN VALUE</td>
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</tr>
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<td>-8.7</td>
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<td>-56.36pA</td>
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<td>218.00</td>
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<td>147.30</td>
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<td>18.61pA</td>
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<td>29.02</td>
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**NOTE:** Catastrophic Rejects removed from data.
<table>
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<th>Parameters</th>
<th>$I_{CBO} = 0.2\text{nA (max)}$</th>
<th>$h_f = 70(\text{min})$</th>
<th>$900(\text{max})$</th>
</tr>
</thead>
<tbody>
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<td>Conditions and Limits</td>
<td>@ $V_{CB} = -25\text{V}, \ I_E = 0$</td>
<td>@ $V_{CE} = -0.5\text{V}, \ I_C = 1.0\text{mA}$</td>
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</tr>
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<td>Raytheon</td>
<td>Teledyne</td>
<td>Raytheon</td>
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<td>MIN VALUE</td>
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<td>70.00pA</td>
<td>90.00</td>
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<td>86.87pA</td>
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**Interim Data**

(Initial to Final)

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<th>Mean Value</th>
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<td>Temp ($T_A$)</td>
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<tr>
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<tr>
<td>320</td>
<td>100°C</td>
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<tr>
<td>480</td>
<td>125°C</td>
</tr>
<tr>
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<td>960</td>
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<td>1280</td>
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<td>1440</td>
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<tr>
<td>1600</td>
<td>300°C</td>
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</table>

**Final Data**

<table>
<thead>
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<th>Final Temp ($T_A$)</th>
<th>275°C</th>
<th>300°C</th>
<th>275°C</th>
<th>300°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN VALUE</td>
<td>10.00pA</td>
<td>60.000pA</td>
<td>12.00</td>
<td>68.00</td>
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<tr>
<td>MAX VALUE</td>
<td>3.332nA</td>
<td>7.440µA</td>
<td>129.00</td>
<td>191.00</td>
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<td>436.000pA</td>
<td>551.700nA</td>
<td>53.47</td>
<td>147.70</td>
</tr>
<tr>
<td>STD DEV</td>
<td>923.700pA</td>
<td>1.843µA</td>
<td>37.58</td>
<td>30.24</td>
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**NOTE:** Catastrophic rejects removed from data.
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<th>PARAMETERS</th>
<th>ICBO = 0.2nA (max)</th>
<th>hFE = 70 (min)</th>
<th>900 (max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONDITIONS AND LIMITS</td>
<td>@ V&lt;sub&gt;CE&lt;/sub&gt; = -25V, I&lt;sub&gt;E&lt;/sub&gt; = 0</td>
<td>@ V&lt;sub&gt;CE&lt;/sub&gt; = -0.5, I&lt;sub&gt;C&lt;/sub&gt; = -1.0mA</td>
<td></td>
</tr>
<tr>
<td>IDENTIFICATION</td>
<td>RAYTHEON</td>
<td>TELEDYNE</td>
<td>RAYTHEON</td>
</tr>
<tr>
<td>INITIAL DATA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIN VALUE</td>
<td>40.00pA</td>
<td>0.00A</td>
<td>107.00</td>
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<tr>
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<td>MEAN</td>
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<td>65.29pA</td>
<td>160.20</td>
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<td>20.61pA</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(∆MEAN VALUE)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Hrs</td>
<td>Temp(T&lt;sub&gt;A&lt;/sub&gt;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>150°C</td>
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<td>-10.00pA</td>
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<tr>
<td>32</td>
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<td>-9.41pA</td>
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<tr>
<td>48</td>
<td>200°C</td>
<td>-10.90pA</td>
<td>-10.58pA</td>
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<tr>
<td>64</td>
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<td>-4.11pA</td>
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<tr>
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<td>-1.17pA</td>
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<tr>
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<td>113.73nA</td>
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<td>FINAL DATA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>300°C</td>
<td>300°C</td>
<td>300°C</td>
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NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA
## TABLE VII
### FINAL DATA SUMMARY

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<th>SPECIFICATIONS LIMIT</th>
<th>UNITS</th>
<th>MEAN INT. DATA</th>
<th>POWER STRESS</th>
<th>TEMPERATURE STRESS I</th>
<th>TEMPERATURE STRESS II</th>
</tr>
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<tr>
<td>I_{CBO}</td>
<td>Min: - Max: 0.2</td>
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<td>- .02384</td>
<td>+.02747</td>
<td>+56.210</td>
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<tr>
<td>h_{FE}</td>
<td>Min: 70 Max: 900</td>
<td>-</td>
<td>- 3.2731</td>
<td>- 23.980</td>
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### AVERAGE Δ IN MEAN VALUE

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<th>TELEDYNE</th>
<th>RAYTHEON</th>
<th>TELEDYNE</th>
<th>RAYTHEON</th>
<th>TELEDYNE</th>
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</thead>
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<td>I_{CBO}</td>
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<td>- .02384</td>
<td>+.02747</td>
<td>+56.210</td>
<td>- .00549</td>
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### NOTE:
Catastrophic reject(s) removed from data.
## TABLE VIII
STEP STRESS CATASTROPHIC FAILURE SUMMARY

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<th>GROUP I</th>
<th>POWER STRESS</th>
<th>TEST STEP</th>
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<th>MFR B</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>50% 50 hr.</td>
<td>0</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
<td>100 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100% 50 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>125% 10 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
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<td></td>
<td>100 hr.</td>
<td>0</td>
<td>0</td>
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<td></td>
<td>100 hr.</td>
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<tr>
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<td></td>
<td>250 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150% 10 hr.</td>
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<td>0</td>
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<tr>
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<td></td>
<td>15 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td></td>
<td>25 hr.</td>
<td>0</td>
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</tr>
<tr>
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<td></td>
<td>250 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>175% 10 hr.</td>
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<td>15 hr.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td></td>
<td>25 hr.</td>
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<td>0</td>
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<tr>
<td></td>
<td></td>
<td>100 hr.</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
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</tr>
<tr>
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<table>
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<th>MFR B</th>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>125°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>150°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>175°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>200°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>225°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>250°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>275°C</td>
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<table>
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<th>TEST STEP</th>
<th>MFR A</th>
<th>MFR B</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>150°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>0</td>
</tr>
<tr>
<td></td>
<td>200°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>225°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>250°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>275°C</td>
<td>0</td>
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</tr>
<tr>
<td></td>
<td>300°C</td>
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<td>0</td>
</tr>
</tbody>
</table>

MFR A → RAYTHEON
MFR B → TELEDYNE

NOTES:

A) \( h_{FE} < 35 \)

B) \( I_{CBO} > 20 \text{nA} \)
## Table IX
### Step Stress Parametric Failure Summary

<table>
<thead>
<tr>
<th>GROUP I Power Stress</th>
<th>MFR A</th>
<th>MFR B</th>
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</thead>
<tbody>
<tr>
<td>TEST STEP</td>
<td>QTY.</td>
<td>NOTE</td>
</tr>
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</tr>
<tr>
<td>100 hr.</td>
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<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>250 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100% 50 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>250 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>125% 10 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>15 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>25 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>250 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>150% 10 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>15 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>25 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>250 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>175% 10 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>15 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>25 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100 hr.</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>250 hr.</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GROUP II 160 HR. Temp. Steps</th>
<th>MFR A</th>
<th>MFR B</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST STEP (T_A)</td>
<td>QTY.</td>
<td>NOTE</td>
</tr>
<tr>
<td>75°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>100°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>125°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>150°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>175°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>200°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>225°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>250°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>275°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>300°C</td>
<td>1</td>
<td>B</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GROUP III 16 HR. Temp. Steps</th>
<th>MFR A</th>
<th>MFR B</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEST STEP (T_A)</td>
<td>QTY.</td>
<td>NOTE</td>
</tr>
<tr>
<td>150°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>175°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>200°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>225°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>250°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>275°C</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>300°C</td>
<td>1</td>
<td>B</td>
</tr>
</tbody>
</table>

Notes:
A) ICBO Maximum Limit Failure
B) h_FE Minimum Limit Failure

MFR A → Raytheon
MFR B → Teledyne
APPENDIX

FAILURE ANALYSIS
INTERNAL VISUAL INSPECTION:

All three Raytheon samples have extensive gold-aluminum intermetallic formation. (See Figure A-1.) The gold wires have alloyed extensively so that their original size and shape are distorted near the die.

CONCLUSIONS:

These samples failed due to catastrophic loss of $h_{FE}$. The absence of shorts, opens, and junction leakage suggests that the loss of $h_{FE}$ was caused by a reduction in emitter efficiency. This emitter degradation was caused by migration of impurities from the intermetallics which acted to reduce lifetime in the bulk silicon.

$h_{FE}$ trace present, Cannot meet stated test conditions.

$h_{FE}$ trace very leaky, $H =$ hysteresis

S = soft, D = drift, Inv = inversion, Uns = unstable, R = resistive
**MSFC STEP-STRESS TEST**  
**FAILURE ANALYSIS - TRANSISTORS**

**J/N 2CN242-10B**

**P/N** JTX2N2945A (PNP)

**MFR:** Teledyne S/C

**Date:** 20 September 1978

**Failure Verification:**

<table>
<thead>
<tr>
<th>S/N</th>
<th>BVCEO -volts-</th>
<th>BVCEO -volts-</th>
<th>ICBO -volts-</th>
<th>BVCEO -volts-</th>
<th>VBEBO -volts-</th>
<th>VBEBO -volts-</th>
<th>INITIAL REJ. @ test sequence</th>
<th>INITIAL REJ. FOR:</th>
</tr>
</thead>
<tbody>
<tr>
<td>4475</td>
<td>35</td>
<td>83</td>
<td>454 nA</td>
<td>43</td>
<td>none*</td>
<td>0.82</td>
<td>MP-11</td>
<td>hFE low</td>
</tr>
<tr>
<td>4476</td>
<td>R</td>
<td>44</td>
<td>10 nA</td>
<td>44</td>
<td>none R</td>
<td>0.86</td>
<td>MP-6</td>
<td>hFE low</td>
</tr>
<tr>
<td>4482</td>
<td>Inv</td>
<td>82</td>
<td>200 nA</td>
<td>42</td>
<td>none*</td>
<td>0.82</td>
<td>MP-10</td>
<td>ICBO</td>
</tr>
</tbody>
</table>

**Internal Visual Inspection:**

S/N 4475 and 4482 have no significant visual defects.

S/N 4476 has an extraneous bit of metallization which crosses the channel-stopper between the emitter and collector areas. (See Figure A-3.)

**Conclusions:**

Teledyne samples 4475 and 4482 have surface leakage due to contamination, as demonstrated by the inversions seen during the BVCEO and ICBO measurements above. This leakage has degraded the hFE.

S/N 4476 has a collector-emitter short caused by the extraneous bit of metallization on the channel-stopper diffusion. (See Figure A-3.)

This was verified by probing between the extraneous metal and the collector or emitter. The metal showed continuity with both structures. This short which may have developed by spot alloying while the die was very hot (See Figure A-3) has destroyed the device function.

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

H = hysteresis  
S = soft  
D = drift  
Inv = inversion  
Uns = unstable  
R = resistive
FIGURE A-1
S/N 4426. MAGNIFICATION 136X.
Typical Raytheon die layout. Note the extensive intermetallic formation.

FIGURE A-2
S/N 4476. MAGNIFICATION 136X.
Typical Teledyne die with mesa geometry.
Arrow: See Figure A-3.
FIGURE A-3
S/N 4476. MAGNIFICATION 400X.
Arrow indicates extraneous spot of metallization on channel-stopper diffusion.