Total-Dose Radiation Effects  
Data for Semiconductor Devices  
1989 Supplement

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February 15, 1990
<table>
<thead>
<tr>
<th>1. Report No.</th>
<th>89-17</th>
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<tr>
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<tr>
<td>4. Title and Subtitle</td>
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</tr>
<tr>
<td>5. Report Date</td>
<td>February 15, 1990</td>
</tr>
<tr>
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<td></td>
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<tr>
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<td>JET PROPULSION LABORATORY California Institute of Technology 4800 Oak Grove Drive Pasadena, California 91109</td>
</tr>
<tr>
<td>10. Work Unit No.</td>
<td></td>
</tr>
<tr>
<td>11. Contract or Grant No.</td>
<td>NAS7-918</td>
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<tr>
<td>12. Sponsoring Agency Name and Address</td>
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</tr>
<tr>
<td>16. Abstract</td>
<td>Steady-state, total-dose radiation test data are provided for electronic designers and other personnel using semiconductor devices in a radiation environment. The data are presented in graphic and narrative formats. All tests were conducted at the Jet Propulsion Laboratory (JPL). Two primary radiation-source types were used: Cobalt-60 gamma rays and a Dynamitron electron accelerator capable of delivering 2.5-MeV electrons at a steady rate. All data were generated in support of National Aeronautics and Space Administration (NASA) Space Projects and Programs by the JPL Radiation Effects and Testing Group (Section 514).</td>
</tr>
<tr>
<td>17. Key Words (Selected by Author(s))</td>
<td>Astronautics; Nuclear Science and Technology (General); Space Sciences (General); Flight Projects (General); Ionizing Radiation Tolerance (Double); Bipolar Transistor Integrated Circuit</td>
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<tr>
<td>18. Distribution Statement</td>
<td>Unlimited/Unclassified</td>
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<tr>
<td>19. Security Classif. (of this report)</td>
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<td>21. No. of Pages</td>
<td>219</td>
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The JPL/NASA electronic data bank called "RADATA" consists of JPL total-dose and Single Event Effects (SEE) ground based test data available for government and industry use. The data bank is accessible via the users personal computer and dial-up modem at no cost to the user. The data bank is completely menu driven and permits the user to peruse the table of contents, view data, and download to their disk drive if desired. Also, data can be requested and received by U.S. postal mail.

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1. Direct dial X4-4360 or access ILAN and connect to the "VLSI" or the "DSFVAX".
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2. After the CONNECT prompt, press the RETURN/ENTER key twice, then input RADATA to the USERNAME prompt and press RETURN/ENTER again.

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1. Dial (818)393-4156 (DSFVAX).
2. After you connect, the screen will go blank. Press RETURN/ENTER twice (the screen will remain blank).
3. Type in RADATA in UPPER CASE LETTERS only (the characters will not be displayed on the screen) then press the RETURN/ENTER key again.

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1. Log-on your VAX computer. Access the JPL computer by inputting SET HOST JPLLSI or SET HOST JPLUP.
2. Enter RADATA to the USERNAME: prompt and press RETURN/ENTER.

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2. Input RADATA to the username prompt and press RETURN/ENTER twice.

After you have logged on the computer, using any of the above access methods, you will be guided by selecting various menus and self help instructions.

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1. Things that I like about the data bank:

   _____________________________________________________________
   _____________________________________________________________
   _____________________________________________________________

2. Things that need improvement:

   _____________________________________________________________
   _____________________________________________________________
   _____________________________________________________________

3. Additional comments:

   _____________________________________________________________
   _____________________________________________________________
   _____________________________________________________________

NAME: __________________________________________ MAIL STOP: __________
AFFILIATION: ______________________________ TELEPHONE: ______________
STREET ADDRESS: _________________________________________________
CITY: _______________ STATE: ___________ ZIP CODE: ______________

SEND REPLY TO:

Jet Propulsion Laboratory
4800 Oak Grove Dr.
Pasadena, CA 91109
C/O Data Bank Manager, M/S 303/220
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ABSTRACT

Steady-state, total-dose radiation test data are provided for electronic designers and other personnel using semiconductor devices in a radiation environment. The data are presented in graphic and narrative formats. All tests were conducted at the Jet Propulsion Laboratory (JPL). Two primary radiation-source types were used: Cobalt-60 gamma rays and a Dynamitron electron accelerator capable of delivering 2.5-MeV electrons at a steady rate.

All data were generated in support of National Aeronautics and Space Administration (NASA) Space Projects and Programs by the JPL Radiation Effects and Testing Group (Section 514).
PREFACE

The 1985 supplement (JPL Publication 85-43) was presented in two volumes, due to the extensive amount of data available. Volume I contained optical diode and transistor data, and Volume II contained integrated circuit data.

The amount of data generated since the October 15, 1985 release of Volume I and the integrated circuit data generated since the May 15, 1986 release was not sufficient to require two volumes. Hence, the 1989 supplement is presented in one book.

For those interested, a Single Event Phenomena (SEP) data book is also available at no cost by writing to:

Jet Propulsion Laboratory
Document Review Group 111-113
4800 Oak Grove Drive
Pasadena, CA 91109


ACKNOWLEDGMENT

The authors would like to acknowledge the skill and dedication of Steven Conrad and Michael Weideman, who were instrumental in providing the data for this publication.

The work in this report was carried out for a number of spacecraft projects and the National Aeronautics and Space Administration (NASA) Microelectronics Radiation Effects Ground Test Program.

The sponsor of this publication is the NASA Office of Safety, Reliability, Maintainability and Hardness Assurance; NASA Headquarters, Code Q.
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SECTION I
INTRODUCTION

The data presented in this 1989 supplement describe the results of Total Ionizing Dose (TID) tests of optical diodes, bipolar transistors, and integrated circuits. The data were obtained by the Jet Propulsion Laboratory (JPL) in order to assure the "hardness" (radiation resistance) of components to be used in a variety of radiation environments; however, the data are applicable to any ionizing (total dose) radiation environment. Two primary radiation-source types were used: Cobalt-60 gamma rays and a Dynamitron electron accelerator capable of delivering 2.5-MeV electrons at a steady rate.

The electrical parameter data are presented in graphic or narrative format for various operating conditions as a function of dose. A measure of the statistical variation of each device lot is provided by the tabulated standard deviations at the bottom of each graph. Where there are irradiations of two or more different lots of a given device type, each lot is treated as an entirely separate test.

All data taken here substantially meet the requirements of MIL-STD-883, method 1019, for environments where short-term annealing is not a relevant problem. Each test consisted of three or more radiation levels at room temperature, and the devices under test were maintained at the established project worst-case bias conditions during the radiation exposure. Electrical parameter measurements were commonly taken within 10 to 60 minutes of completion of irradiation.
SECTION II
DOCUMENT USES AND LIMITATIONS

The purpose of this report is to provide test data for optical diodes, transistors, and integrated circuits exposed to steady-state ionizing radiation. As such, it offers a useful comparison of the radiation response of different devices that might be considered in the development (circuit design) of a radiation-hardened system. It also offers a quick method for determining the weak links in an existing system, and an approximation of the system radiation tolerance as a whole.

The data presented here cannot be used as a substitute for a comprehensive testing program of the devices actually used in a given system. It will be clear on inspecting the data herein that there are large lot-to-lot or wafer-to-wafer variations in the sample responses of a given device type. The response difference from functionally identical devices fabricated by different manufacturers is even greater. There was no attempt to remove "maverick" (outlier) devices from the data plots, so some data plots may appear anomalous when compared to other plots for the same device type. It should be noted that given manufacturers may make minor adjustments in their processing procedures that will result in a major difference in the device radiation response.
SECTION III
RADIATION SOURCES AND DOSIMETRY

A. DYNAMITRON

Some of the transistor tests were performed using the JPL Dynamitron electron accelerator which provided a 2.5-MeV electron beam with beam currents ranging from $10^8$ to $10^{10}$ electrons/cm$^2$/second. The tests described here were irradiated at a given fluence level for exposure times between 5 and 45 minutes.

The test geometry for the Dynamitron facility consisted of an electron beam brought out of the beam tube through a 0.05-mm titanium window, copper and aluminum scattering foils, and 0.9 m of air. Each of these materials scatters the electrons slightly so that the scattered beam has a uniformity variation of less than 20 percent over the test device array, which is confined within a 25-cm-diameter circle perpendicular to the beam direction. At the center of the circle is the aperture of a vacuum Faraday cup, which is used to measure the electron beam flux and fluence. The beam is centered on the Faraday cup with a quadrupole magnet prior to the installation of the test samples. The output from the Faraday cup is a current that is fed into a current integrator, which is calibrated daily against a standard current source. The integrator is set to shut off the electron beam automatically when the desired fluence level is received at the Faraday cup.

B. COBALT-60 SOURCES

The JPL Cobalt-60 gamma ray source was used for all of the IC tests. The gamma rays consisted primarily of 1.17 and 1.33 MeV photons with lower energy photons and secondary electrons arising from scattering and absorption. The gamma field was uniform within ±10 percent in the parts exposure area, which was verified by thermoluminescent dosimetry (TLD), consisting of lithium fluoride/Teflon microrods. The main source calibration was performed with Landsverk ion chambers of ±2 percent accuracy, traceable to the National Bureau of Standards, and monthly dose rate computations performed to account for the radioactive decay of the Cobalt-60 source. Exposure times with the Cobalt-60 sources were typically 5 to 20 minutes for each radiation level. Longer times (up to 4 hours) were required for high total dose exposures because the maximum uniform dose rate available was 100 rads (Si)/second.

Dose rate testing was performed from 100 rad(Si)/second to 0.0058 rad(Si)/second with a corresponding increase in time for the low rates.
SECTION IV
TEST SETUP AND PROCEDURES

A. GENERAL REMARKS

The test setup and procedures used here were developed in accord with the specifications of MIL-STD-883, method 1019. All tests were done at 25 °C ± 3 °C, using low noise power sources and instrumentation subject to periodic calibration. Some tests were performed in situ (without removing the test devices from the radiation area), whereas others required remote testing, using a mobile bias fixture to maintain bias except during the brief measurement period.

A detailed test plan was written for each test including test device description, irradiation bias conditions, radiation levels, electrical parameters to be measured, and measurement conditions. The data were processed by computer with the calculation of normal means and standard deviations made after deletion of clearly erroneous data. Individual data can be retrieved, if required, by specifying the JPL log number given with each data plot to the Radiation Effects and Testing Group (Section 514) at JPL.

B. TRANSISTORS AND OPTICAL DEVICES

Transistors and optical devices were measured in situ using a matrix board switching panel set up outside the irradiation area. The matrix board interfaces the devices under test (DUT) to the power supplies and measurement equipment via a special 15-m (50-ft), double-shielded cable (Figure 4-1). A built-in potentiometer for each DUT could be used to control bias voltages and currents. The matrix board was designed with very high insulation resistance so that very low current measurements (10-50 pA) could be made.

C. INTEGRATED CIRCUIT TESTING

For non-in situ remote tests the DUTs were removed from the radiation site for approximately 10 to 60 minutes between each radiation level. A mobile bias (battery) was applied to the devices at all times except during parameter measurements. Remote measurements were performed using a Tektronix 178/577 curve tracer, a Hewlett Packard 4062C, Semiconductor Parametric Test System, or a bench fixture. Occasionally, custom-built test circuits were used to simulate the circuit application of the devices tested, such as a grounded, shielded, low current measurement fixture.
Figure 4-1. Block Diagram of the Test Setup for in situ Testing with the Electron Accelerator (Dynamitron)
SECTION V
DATA PRESENTATION

A. BIPOLAR TRANSISTORS

The transistor data presented in graphic format are shown in Figure 5-1. Each of the electrical parameter data plots is represented by multiple lines to represent different collector currents. A table at the bottom of each graph lists the test conditions, when applicable, and the normal standard deviations of each data point at each dose level.1

Date codes usually indicate when the device was packaged. For example, 8420 indicates the device was packaged in the twentieth week of 1984. If no date code is available, the space may be used for other identifying numbers such as wafer number or lot number.

For convenience, the degradation in transistor gain \( h_{FE} \) is plotted as

\[
\Delta(1/h_{FE}) = 1/h_{FEj} - 1/h_{FEo},
\]

where \( h_{FEj} \) is the value at the specified radiation level, and \( h_{FEo} \) is the initial value. Implicit in this approach is the assumption that the radiation behavior can be approximated by the well-known formula:

\[
\Delta(1/h_{FE}) = K\phi
\]

where \( \phi \) is the dose (or fluence) and \( K \) is a damage constant that depends on the device type and collector current, \( I_C \).

A method of determining the final \( h_{FE} \), when the initial \( h_{FE} \) and postirradiation \( \Delta(1/h_{FE}) \) are known, is shown in the following example for a 2N2222 device type at \( V_{CE} \) of 20 V at 300 krad(Si).

1. Scale the value of \( \Delta(1/h_{FE}) \) from the applicable graph for a 2N2222 transistor at the stated conditions. In this example, \( \Delta(1/h_{FE}) \) is determined to be 0.008.

2. Determine the minimum specified preirradiation \( h_{FE} \) for this device type. In this example, the initial specified minimum \( h_{FE} \) is 100. Then proceed as follows:

\[
h_{FE}(final) = \frac{1}{\Delta(1/h_{FE}) + h_{FEo}(initial)} \]

\[
h_{FE}(final) = \frac{1}{0.008 + \frac{1}{100}} = 55.6
\]

The log-normal distribution actually provides a better fit to most radiation data than the normal distribution. Hence, caution should be exercised in estimating worst-case conditions based on the limited statistical data presented herein.
Table 5-1 may also be used to determine the final $h_{FE}$. Locate the postirradiation $\Delta(1/h_{FE})$ value in the left-hand column, and the initial $h_{FE}$ on the top row. The column and row intersection is the final $h_{FE}$.

Table 5-1

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Mean Parameter Value

Dose and Source

Figure 5-1. Graph Format Description
| $\Delta h_{FE}$ | 10 | 12 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 110 | 120 | 130 | 140 | 150 | 170 | 200 | 250 | 300 | 350 | 400 |
|----------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| .0025 | 5.93 | 11.8 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 48.8 | 53.1 | 58.1 | 62.9 | 67.2 | 71.6 | 75.0 | 78.2 | 81.3 | 84.2 | 87.0 | 89.7 | 92.2 | 94.3 | 96.3 | 98.2 | 100 | 102 |
| .0050 | 9.32 | 14.9 | 18.1 | 23.4 | 28.4 | 33.6 | 38.9 | 44.3 | 49.8 | 55.3 | 60.6 | 66.1 | 71.6 | 77.2 | 82.6 | 88.0 | 93.5 | 99.0 | 104 | 109 | 115 | 120 | 126 | 132 | 138 | 144 | 150 |
| .0100 | 9.44 | 14.9 | 18.1 | 23.4 | 28.4 | 33.6 | 38.9 | 44.3 | 49.8 | 55.3 | 60.6 | 66.1 | 71.6 | 77.2 | 82.6 | 88.0 | 93.5 | 99.0 | 104 | 109 | 115 | 120 | 126 | 132 | 138 | 144 | 150 |
| .0150 | 9.44 | 14.9 | 18.1 | 23.4 | 28.4 | 33.6 | 38.9 | 44.3 | 49.8 | 55.3 | 60.6 | 66.1 | 71.6 | 77.2 | 82.6 | 88.0 | 93.5 | 99.0 | 104 | 109 | 115 | 120 | 126 | 132 | 138 | 144 | 150 |
| .0200 | 9.44 | 14.9 | 18.1 | 23.4 | 28.4 | 33.6 | 38.9 | 44.3 | 49.8 | 55.3 | 60.6 | 66.1 | 71.6 | 77.2 | 82.6 | 88.0 | 93.5 | 99.0 | 104 | 109 | 115 | 120 | 126 | 132 | 138 | 144 | 150 |
| .0250 | 9.44 | 14.9 | 18.1 | 23.4 | 28.4 | 33.6 | 38.9 | 44.3 | 49.8 | 55.3 | 60.6 | 66.1 | 71.6 | 77.2 | 82.6 | 88.0 | 93.5 | 99.0 | 104 | 109 | 115 | 120 | 126 | 132 | 138 | 144 | 150 |
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| .0350 | 9.44 | 14.9 | 18.1 | 23.4 | 28.4 | 33.6 | 38.9 | 44.3 | 49.8 | 55.3 | 60.6 | 66.1 | 71.6 | 77.2 | 82.6 | 88.0 | 93.5 | 99.0 | 104 | 109 | 115 | 120 | 126 | 132 | 138 | 144 | 150 |

Table 5-1. Determination of Final $h_{FE}$, Given Initial $h_{FE0}$ and Postirradiation $\Delta(1/h_{FE})$.
TABLE OF NORMAL STANDARD DEVIATIONS

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DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MOT 5 DEVICES TEST DATE 2-04-86
REF: JPL LOG 1225 DATE CODE 8530

\[ \Delta \left( \frac{1}{h_{FE}} \right) \text{ VS DOSE} \]

**DOSE, rads(Si) 2.5 MeV electrons**

\( \Delta \left( \frac{1}{h_{FE}} \right) \text{ VS DOSE} \)

**TABLE OF NORMAL STANDARD DEVIATIONS**

<table>
<thead>
<tr>
<th>CURVE</th>
<th>I_e (mA)</th>
<th>V_CE (V)</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>7.5E4 1.5E5 3.0E5 6.0E5 1.0E6</td>
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TABLE OF NORMAL STANDARD DEVIATIONS

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<th>$V_{CC}$</th>
<th>DOSE, rad(Si)</th>
<th>$\Delta(1/h_{FC})$</th>
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<td>[V]</td>
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<th>DOSE, rads(Si)</th>
<th>$\Delta(1/\beta)$</th>
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</table>

**DOSE, rads(Si):** 2.5 MeV electrons

$\Delta(1/\beta)$ VS DOSE
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MDT 3 DEVICES TEST DATE 2-04-86
REF: JPL LOG 1228 DATE CODE 8530

DOSE, rads(Si) 2.5 MeV electrons
\[\Delta(1/h_{fe}) \text{ VS DOSE}\]

<table>
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<tr>
<th>CURVE</th>
<th>Ic (mA)</th>
<th>Vce (v)</th>
<th>DOSE, rads(Si)</th>
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<tr>
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<td>.0026</td>
<td>6.0E5</td>
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<td>.0026</td>
<td>1.0E6</td>
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<tr>
<td>F</td>
<td>500.00</td>
<td>.0026</td>
<td>1.5E6</td>
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DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MOT 5 DEVICES TEST DATE 2-04-86
REF: JPL LOG 1229 DATE CODE 8530

DOSE, rads(Si) 2.5 MeV electrons

\( \Delta(1/h_{FE}) \) VS DOSE

**TABLE OF NORMAL STANDARD DEVIATIONS**

<table>
<thead>
<tr>
<th>CURVE</th>
<th>( I_c ) (mA)</th>
<th>( V_{dc} ) (V)</th>
<th>DOSE, rads(Si)</th>
<th>( 7.5E4 )</th>
<th>( 1.5E5 )</th>
<th>( 3.0E5 )</th>
<th>( 6.0E5 )</th>
<th>( 1.0E6 )</th>
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</thead>
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<tr>
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<td>20.00</td>
<td>0.0015</td>
<td>0.0017</td>
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<td>0.0023</td>
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<td>5.0000</td>
<td>0.0014</td>
<td>0.0022</td>
<td>0.0029</td>
<td>0.0056</td>
<td>0.0067</td>
<td>0.0029</td>
</tr>
<tr>
<td>C</td>
<td>1.0000</td>
<td>5.0000</td>
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<td>0.0007</td>
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<td>0.0017</td>
<td>0.0009</td>
<td>0.0009</td>
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<td>20.00</td>
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5-9
**Device Type:** 2N2222A NPN Transistor  
**MFG:** MOTOR 3 DEVICES  TEST DATE 02-04-86  
**REF:** JPL LOG 1230  DATE CODE 8530

**Graph:**  
DOSE, rads(Si), 2.5 MeV electrons  
$\Delta(1/h_{\text{ref}})$ VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>$I_e$</th>
<th>$V_{ce}$</th>
<th>DOSE, rads(Si)</th>
<th>$\Delta(1/h_{\text{ref}})$</th>
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<tr>
<td>A</td>
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<td>20.0</td>
<td>7.564 1.565 3.055 6.055</td>
<td>0.0045 0.0031 0.0017 0.0005</td>
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<tr>
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<td>0.0041 0.0020 0.0017 0.0006</td>
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<td>20.0</td>
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<td>D</td>
<td>20.0</td>
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<td>6.055 1.066</td>
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<td>0.000</td>
<td>0.000</td>
<td>1.066</td>
<td>0.0004 0.0003 0.0007 0.0003</td>
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<tr>
<td>F</td>
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<td>0.000</td>
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DEVICE TYPE: 2N2222A NPN TRANSMITOR
MFG: MOT 5 DEVICES TEST DATE 02-05-86
REF: JPL LOG 1231 DATE CODE 8530

DOSE, rads(Si) 2.5 MeV electrons
\(\Delta(1/h_{FE}) VS DOSE\)

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>(I_c) (mA)</th>
<th>(V_{CE}) (v)</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>20.0</td>
<td>7.5E4, 1.5E3, 3.0E3, 6.0E3, 9.0E3</td>
</tr>
<tr>
<td>B</td>
<td>0.1000</td>
<td>500</td>
<td>1.0E-4, 5.0E-5, 2.0E-6</td>
</tr>
<tr>
<td>C</td>
<td>1.000</td>
<td>500</td>
<td>1.0E-4, 5.0E-5, 2.0E-6</td>
</tr>
<tr>
<td>D</td>
<td>1.000</td>
<td>20.0</td>
<td>1.0E-4, 5.0E-5, 2.0E-6</td>
</tr>
<tr>
<td>E</td>
<td>20.00</td>
<td>20.0</td>
<td>1.0E-4, 5.0E-5, 2.0E-6</td>
</tr>
<tr>
<td>F</td>
<td>20.00</td>
<td>500</td>
<td>1.0E-4, 5.0E-5, 2.0E-6</td>
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DE-VICE TYPE: 2N3749 NPN POWER TRANSISTOR
MFG: AEC
3 DEVICES TEST DATE 12-19-85
REF: TPL LOG 1211 DATE CODE 8510

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
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<tr>
<th>CURVE</th>
<th>Ic (mA)</th>
<th>Vce (V)</th>
<th>DOSE, rods(Si) Co^{60} Gammas</th>
<th>Δ(1/h_{fe})</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>0.0008 .0013 .0013 .0023 .0038</td>
</tr>
</tbody>
</table>

DOSE, rods(Si) Co^{60} Gammas

Δ(1/h_{fe}) VS DOSE
DOSE, rads(Si) Co⁶⁰ Gammas
Δ(1/\text{h}_{\text{Fe}}) VS DOSE

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<th>V_C</th>
<th>DOSE, rads(Si)</th>
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</tr>
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<td>5.0</td>
<td>0.0016 0.0036 0.0040 0.0045 0.0045</td>
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<tr>
<td>B</td>
<td>10.0</td>
<td>5.0</td>
<td>0.0022 0.0026 0.0028 0.0027 0.0031</td>
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TABLE OF NORMAL STANDARD DEVIATIONS
DEVICE TYPE: MJ16012 NPN POWER TRANSISTOR
MFG: MOT 5 DEVICES TEST DATE 12-17-85
REF: JPL LOG 1220 DATE CODE NONE

TABLE OF NORMAL STANDARD DEVIATIONS

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<tr>
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<th>$V_{CE}$ [V]</th>
<th>$\text{Dose, rad(Si)}$</th>
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<td>0.0013</td>
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TABLE OF NORMAL STANDARD DEVIATIONS

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<th>CURVE</th>
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<th>V_CE</th>
<th>DOSE, rads(Si) Co\textsuperscript{60} Gamman</th>
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</table>
B. OPTICAL DEVICES

The optical data are presented in a combined narrative, tabular, and graphic format.

The TIL24 devices were measured using a TIL604 photo transistor as a reference sensor, placed 1/4 in. from the source being measured. The TIL604 devices were measured using a single TIL24 near-infrared-emitting diode as the light source, placed 1/4 in. away from the base of the photo transistor.
Device Type: TIL24 BIPOLAR PN GaAs INFRARED-EMITTING DIODES  
Manufacturer: Texas Instruments Inc. (TIX)  
Date Code:  
Package Type: PILL  
No. of Devices Tested: 2 LOG 1261; 7 (6 + Control) LOG 1260  
Radiation Test Requirement (RTR) S/N: 100 C  
Log No.: 1260, 1261  
Radiation Test Date: 10-July-86  
Facility: DYNAMITRON  
Energy: 2.5 MeV  
Dose Rate: 1.3E08, 4.0E08, 4.0E09, increasing with dose (see RTR 100C)  
Dose: 4.0E10 to 2.0E12 [e/cm²] or 1.0E3 to 5.0E5 [rad(Si)]

In the discussion below, only the parameters that failed are discussed; all other parameters met the manufacturers' specifications out to 50 krad(Si). It is recommended that this device not be used above 10 krad(Si) at the 50 mA drive level unless special design considerations are made to account for the observed failures. Postirradiation measurements were made at 2, 20, and 100 hours after irradiation. The annealing behavior should be taken into account, because the extremely low dose rates in space will allow significant annealing and possibly permit use of this part up to the 30 krad(Si) dose level, based on the specification of 1 mW at 50 mA drive. Use at current drives lower than 50 mA should be done with extreme caution, because the nonlinearity in the power curve with current indicates the possibility of premature failure at low current drives (power output is below 1 mW at 40 mA preirradiation and decreases exponentially with lower currents).

The TIL24 bipolar pn GaAs infrared-emitting diode is designed to emit near-infrared radiation spectrally compatible with silicon sensors. It is designed to have high power efficiency, high power output, and to permit matrix assembly directly to printed circuit boards.

Failure levels are taken as parameter changes exceeding the manufacturers' specifications or reasonable preset changes, even though it is realized that some failures to meet specifications can be overcome by clever design.

These devices were irradiated according to RTR S/N 100 C, which gives the bias conditions during irradiation and lists the parameters measured and the measurement conditions. All measurements of light output from the TIL24 were relative measurements, using a single TIL604 phototransistor as a reference sensor placed a fixed distance (1/4 in.) from the source being measured. The RTR and the data are available, if required.

The TIL24 GaAs infrared-emitting diodes were kept under radiation bias after completion of irradiation to 50 krad(Si), and were measured at 2, 20, and 100 hours of anneal time. The TIL24 showed significant recovery of output power for all tested conditions.
Device Type: TIL24 BIPOLAR PN GaAs INFRARED-EMITTING DIODES

Failure Summary:

The mean light emitted in response to various inputs as a function of dose is shown in Table 1 for the preirradiation, 10, 20, 50 krad(Si) levels as well as for the 2, 20, and 100 hours anneal time measurements. While the TIL24 remained functional out to the 50 krad(Si) dose level, the light output had fallen by roughly a factor of two at the 20 krad(Si) dose level and continued to degrade with increasing dose.

Table 1. Output Power at Various Currents Versus Dose Level with Input Light Reference Current (IF) as a Parameter.

<table>
<thead>
<tr>
<th>Po @ IF(mA)</th>
<th>PRE</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>2 hr</th>
<th>20 hr</th>
<th>100 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>390.0</td>
<td>256.3</td>
<td>176.3</td>
<td>63.8</td>
<td>108.8</td>
<td>218.8</td>
<td>260.0 mW</td>
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<td>1558.0</td>
<td>1163.0</td>
<td>868.8</td>
<td>368.8</td>
<td>568.8</td>
<td>977.5</td>
<td>1114.0 mW</td>
</tr>
<tr>
<td>80</td>
<td>2112.0</td>
<td>1629.0</td>
<td>1250.0</td>
<td>565.0</td>
<td>833.8</td>
<td>1366.0</td>
<td>1548.0 mW</td>
</tr>
<tr>
<td>100</td>
<td>2623.0</td>
<td>2623.0</td>
<td>1620.0</td>
<td>772.5</td>
<td>1097.0</td>
<td>1741.0</td>
<td>1954.0 mW</td>
</tr>
</tbody>
</table>

These data are plotted in the following graph, which shows output phototransistor current versus LOG(Dose and Time), with the drive current of the light source and/or the incident light energy as a parameter.

The other parameters were measured as a function of dose level and did not exceed the manufacturers' specifications or change significantly with dose up to the 50 krad(Si) dose level.

These devices were irradiated according to RTR S/N 100 C which gives the bias conditions during irradiation and lists the parameters measured and the measurement conditions. The RTR and the data are available if required.

The parameters measured were (RTR 100 C):

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Symbol</th>
<th>Test Name</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VF-1</td>
<td>FORWARD VOLTAGE</td>
<td>IF = 20 mA</td>
</tr>
<tr>
<td>2</td>
<td>VF-2</td>
<td>FORWARD VOLTAGE</td>
<td>IF = 40 mA</td>
</tr>
<tr>
<td>3</td>
<td>VF-3</td>
<td>FORWARD VOLTAGE</td>
<td>IF = 60 mA</td>
</tr>
<tr>
<td>4</td>
<td>VF-4</td>
<td>FORWARD VOLTAGE</td>
<td>IF = 80 mA</td>
</tr>
<tr>
<td>5</td>
<td>VF-5</td>
<td>FORWARD VOLTAGE</td>
<td>IF = 100 mA</td>
</tr>
<tr>
<td>6</td>
<td>Po-1</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 20 mA</td>
</tr>
<tr>
<td>7</td>
<td>Po-2</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 40 mA</td>
</tr>
<tr>
<td>8</td>
<td>Po-3</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 60 mA</td>
</tr>
<tr>
<td>9</td>
<td>Po-4</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 80 mA</td>
</tr>
<tr>
<td>10</td>
<td>Po-5</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 100 mA</td>
</tr>
</tbody>
</table>
- Normalized $P_0$ [mW/cm$^2$] DATA -

4/27/87

LOG1260: Data TIX TIL24 Bipolar PN GaAs Infrared-Emitting Diodes

$-\text{Normalized } P_0$ [mW/cm$^2$] DATA -

$\text{krad (Si) Hours}$

$\text{Po } @ \text{IF} = 20\text{mA}$

$\text{Po } @ \text{IF} = 40\text{mA}$

$\text{Po } @ \text{IF} = 60\text{mA}$

$\text{Po } @ \text{IF} = 80\text{mA}$

$\text{Po } @ \text{IF} = 100\text{mA}$
Device Type: TIL604 BIPOLAR NPN PLANAR SILICON PHOTOTRANSISTOR
Manufacturer: Texas Instruments Inc. (TIX)
Date Code: 8507
Package Type: PILL
No. of Devices Tested: 2 LOG 1258; 7 (6 + Control) LOG 1259
Radiation Test Requirement (RTR) S/N: 412
Log No.: 1258, 1259
Radiation Test Date: 09-July-86
Facility: DYNAMITRON
Energy: 2.5 MeV
Dose Rate: 1.3E08, 4.0E08, 4.0E08, increasing with level (see RTR 412)
Dose: 4.0E10 to 2.0E12 [e/cm²] or 1.0E3 to 5.0E5 [rad(Si)]

In the discussion below, only the parameters that failed are discussed; all other tested parameters met the manufacturers' specifications out to 50 krad(Si). It is recommended that this device not be used above 10 krad(Si) unless special design considerations to account for the observed degradations are made.

The TIL604 is a bipolar, nonplanar silicon phototransistor in a hermetically sealed pill package that can be assembled into printed circuit boards. The TIL604 is recommended for applications in character recognition, tape and card readers, velocity indicators, and encoders.

Failure levels are taken at parameter changes exceeding the manufacturers' specifications or reasonable preset changes, even though it is realized that some failures to meet specifications can be overcome by clever design.

These devices were irradiated according to RTR S/N 412, which gives the bias conditions during irradiation and lists the parameters measured and the measurement conditions. The TIL604 phototransistors were tested using a single TIL near-infrared-emitting diode as the light source a fixed distance (1/4 in.) away. The current for the reference diode was varied to give a reasonable range of collector currents values in the tested phototransistor, prior to radiation exposure. The RTR and the data are available, if required.

The TIL604 phototransistors were kept under the radiation bias after completion of irradiation to 50 krad(Si), and were measured at 16 and 120 hours of anneal time. No significant annealing of the TIL604 was observed.

Failure Summary:

The mean light current response to various light inputs as a function of dose level is shown in Table 1 for the preirradiation, 10, 20, and 50 krad(Si) levels, as well as for the 16- and 120-hour anneal time measurements. While the TIL604 phototransistors remained functional out to the 50 krad(Si) dose level, the light current had fallen by roughly a factor of two at the 10 krad(Si) level, and continued to degrade with increasing dose levels.
Device Type: TIL604 BIPOLAR NPN PLANAR SILICON PHOTOTRANSISTOR

Failure Summary (Cont):

Table 1. I-LITE Versus Dose Level with Input Light Reference Current (IF) as a Parameter

<table>
<thead>
<tr>
<th>I-LITE (mA) @ IF=20 mA</th>
<th>PRE</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>16 hr</th>
<th>120 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mA (7 mW/cm²)</td>
<td>4.070</td>
<td>1.927</td>
<td>1.426</td>
<td>0.845</td>
<td>0.920</td>
<td>0.883 mA</td>
</tr>
<tr>
<td>40 mA (17 mW/cm²)</td>
<td>9.001</td>
<td>5.170</td>
<td>4.197</td>
<td>2.784</td>
<td>2.957</td>
<td>2.951 mA</td>
</tr>
<tr>
<td>60 mA (20 mW/cm²)</td>
<td>13.170</td>
<td>7.782</td>
<td>6.547</td>
<td>4.579</td>
<td>4.819</td>
<td>4.874 mA</td>
</tr>
<tr>
<td>80 mA (27 mW/cm²)</td>
<td>16.410</td>
<td>10.290</td>
<td>8.824</td>
<td>6.254</td>
<td>6.548</td>
<td>6.671 mA</td>
</tr>
<tr>
<td>100 mA (100 mW/cm²)</td>
<td>18.850</td>
<td>12.490</td>
<td>10.810</td>
<td>7.713</td>
<td>8.042</td>
<td>8.225 mA</td>
</tr>
</tbody>
</table>

These data are plotted in the following graph, which shows output phototransistor current versus LOG (Dose and Time), with the drive current of the light source and/or the incident light energy as a parameter.

The other parameters were measured as a function of dose level and did not exceed the manufacturers' specifications or change significantly with dose up to the 50 krad(Si) dose level.

These devices were irradiated according to RTR S/N 412 which gives the bias conditions during irradiation and lists the parameters measured and the measurement conditions. The RTR and the data are available, if required.

The parameters measured were (RTR 412):

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Symbol</th>
<th>Test Name</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BVCEO</td>
<td>REVERSE BREAKDOWN VOLTAGE</td>
<td>IC = 100 µA</td>
</tr>
<tr>
<td>2</td>
<td>I-DARK</td>
<td>DARK CURRENT</td>
<td>VCE = 30 V</td>
</tr>
<tr>
<td>3</td>
<td>I-LITE1</td>
<td>LIGHT CURRENT</td>
<td>VCE = 5 V, IF = 20 mA from reference source</td>
</tr>
<tr>
<td>4</td>
<td>I-LITE2</td>
<td>LIGHT CURRENT</td>
<td>VCE = 5 V, IF = 40 mA from reference source</td>
</tr>
<tr>
<td>5</td>
<td>I-LITE3</td>
<td>LIGHT CURRENT</td>
<td>VCE = 5 V, IF = 60 mA from reference source</td>
</tr>
<tr>
<td>6</td>
<td>I-LITE4</td>
<td>LIGHT CURRENT</td>
<td>VCE = 5 V, IF = 80 mA from reference source</td>
</tr>
<tr>
<td>7</td>
<td>I-LITE5</td>
<td>LIGHT CURRENT</td>
<td>VCE = 5 V, IF = 100 mA from reference source</td>
</tr>
<tr>
<td>8</td>
<td>VCE(SAT)</td>
<td>OUTPUT SATURATION VOLTAGE</td>
<td>IC = 0.4 mA, IF = 70 mA from reference source</td>
</tr>
</tbody>
</table>
NORMALIZED I-LITE DATA
4/27/87

LOG1258: Data TIX TIL604 NPN Planar Silicon Phototransistor

- I-LITE @ IF = 20mA
- I-LITE @ IF = 40mA
- I-LITE @ IF = 60mA
- I-LITE @ IF = 80mA
- I-LITE @ IF = 100mA
C. INTEGRATED CIRCUITS

The data are presented in graphic format using the normal distribution. The graph format varies depending on the test requirements. Some graphs present a table of standard deviations at the bottom (Figure 5-2), others have more than one plot per paragraph, with or without post irradiation effects (PIE) data in hours following end of radiation (EOR) plots (Figure 5-3). Tests investigating dose rate effects indicate the test dose rate on the graph.

![Graph Format Example](image)

Figure 5-2. Typical Integrated Circuit Graph Format Example

The log-normal or other types of distributions may provide a better fit for some radiation data than the normal distribution. Hence, caution should be exercised in estimating worst-case conditions based on the limited statistical data presented here.
Figure 5-3. Alternate Integrated Circuit Graph Format Example
DEVICE TYPE: 54AC374 OCTAL D-TYPE FIF
MFG: FSC 3 DEVICES TEST DATE 2-11-87
REF: JPL LOG 1296 DATE CODE 8633

PARAMETERS CONDITIONS

CURVE A: (3) VOL1-A (V) (IOUT = 20 MA)
CURVE B: (6) VOL1-B (V) *
CURVE C: (7) VOL2-A (V) (IOUT = 24 MA)
CURVE D: (6) VOL2-B (V) *

Dose, rads(Si) Co60 Gammas

PARAMETERS

CONDITIONS

PRE-READ 10^3 1.5 2 3 4 5 6 7 8 9 10

TIME, hours

10^1 10^2 10^3 10^4 10^5
DEVICE TYPE: 54AC374 OCTAL D-TYPE F/F
MFG: FSC 3 DEVICES TEST DATE 2-11-87
REF: JPL LOG 1296 DATE CODE 8633

PARAMETERS CONDITIONS
CURVE A: (9) IIH-A (A) (VIN = VCC)
CURVE B: (10) III-B (A) * *
CURVE C: (11) III-A (A) (VIN = GND)
CURVE D: (12) III-B (A) * *
DEVICE TYPE: 54AC374 OCTAL D-TYPE F1F
MFG: FSC 3 DEVICES TEST DATE 2-11-67
REF: JPL LOG 1296 DATE CODE 8633

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I02H1-A (A)</td>
<td>(VIN = 3.66 V)</td>
</tr>
<tr>
<td>B</td>
<td>I02H1-B (A)</td>
<td>*</td>
</tr>
<tr>
<td>C</td>
<td>I02H2-A (A)</td>
<td>(VIN = 3.64 V)</td>
</tr>
<tr>
<td>D</td>
<td>I02H2-B (A)</td>
<td>*</td>
</tr>
</tbody>
</table>

DOSE, rads(Si) Co60 Gammas vs. TIME, hours
PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>102L1-A (A)</td>
<td>(VIN = 3.66 V)</td>
</tr>
<tr>
<td>B</td>
<td>102L1-B (A)</td>
<td>*</td>
</tr>
<tr>
<td>C</td>
<td>102L2-A (A)</td>
<td>(VIN = 1.64 V)</td>
</tr>
<tr>
<td>D</td>
<td>102LZ-B (A)</td>
<td>*</td>
</tr>
</tbody>
</table>

DOSAGE, rads(Si) Co^{60} Gammas  TIME, hours
DEVICE TYPE: 54AC374 OCTAL D-TYPE FF
MFG: FSC 3 DEVICES TEST DATE 2-11-67
REF: JPL LOG 1296 DATE CODE 6633

PARAMETERS
CURVE A: (21) ICON-A (A)
CURVE B: (23) ICCL-A (A)
CURVE C: (25) ICCZ-A (A)
DEVICE TYPE: 5406C74 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 4300 DATE CODE 6627

PARAMETERS

CURVE A: (1) VOH=3-A (V) (IOUT = -20 UA)
CURVE B: (2) VOH=3-B (V)

CONDITIONS

DOSE, rads(Si) Co60 Gammas

TIME, hours

PARAMETER MEAN VALUE

10^{-1}

10^{0}

10^{1}

10^{2}

10^{3}

10^{4}

10^{5}

10^{6}

10^{7}

10^{8}

10^{9}

10^{10}

5-31
DEVICE TYPE: 54AC374 OCTAL D-TYPE FIF
MFG: NSC 3 DEVICES TEST DATE 3-24-77
REF: JPL LOG 1300 DATE CODE: 8627

PARAMETERS

CURVE A: (5) VOL1-A (V) (IOUT = 20 MA)
CURVE B: (6) VOL1-B (V)
CURVE C: (7) VOL2-A (V) (IOUT = 5.2 MA)
CURVE D: (8) VOL2-B (V)

CONDITIONS

Dose, rods(Si) Co$^{60}$ Gammas

5-33
PARAMETERS

CURVE A: (11) H+ (A)  [V(IN) = VCC]
CURVE B: (10) H+ (A)  *
CURVE C: (11) H- (A)  [V(IN) = GND]
CURVE D: (12) H- (A)  *

CONDITIONS

PRE-PAD

DOSE, rads(Si) Co60 Gammas

EOR

TIME, hours

PARAMETER MEAN VALUE

DEVICE TYPE: 54AC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1300 DATE CODE 8627
DEVICE TYPE: 54AC374 OCTAL D-TYPE F1/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1300 DATE CODE 8627

<table>
<thead>
<tr>
<th>CURVE A:</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(13) 102H3-A (A)</td>
<td>(VIN = 4.2 V)</td>
<td></td>
</tr>
<tr>
<td>CURVE B:</td>
<td>(14) 102H3-B (A)</td>
<td>*</td>
</tr>
<tr>
<td>CURVE C:</td>
<td>(15) 102H2-A (A)</td>
<td>(VIN = 2.2 V)</td>
</tr>
<tr>
<td>CURVE D:</td>
<td>(16) 102H2-B (A)</td>
<td>*</td>
</tr>
</tbody>
</table>

DOSE, rads(Si) Co$^{60}$ Gammas vs. TIME, hours

PARAMETER MEAN VALUE

PRE-RAD 5 4 3 2 1 0
DOP 5 4 3 2 1 0

5-35
DEVICE TYPE: 54AC374 OCTAL D-TYPE FF

MFG: NSC

2 DEVICES

TEST DATE 3-24-67

REF: JPL LOG 1300

DATE CODE 6627

PARAMETERS CONDITIONS

CURVE A: (17) 10ZL1-A (A) [VIN = 4.2 V]

CURVE B: (18) 10ZL1-B (A) [ ]

CURVE C: (20) 10ZL2-E (A) [VIN = 1.2 V]
DEVICETYPE: 54AC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1300 DATE CODE 8627

PARAMETERS

CURVE A: (21) JCC1-A (A)
CURVE B: (22) JCC2-A (A)
CURVE C: (23) JCCZ-A (A)
DEVICE TYPE: 54AC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1900 DATE CODE 8627

PARAMETERS
CURVE A: (22) IC61-B (A1)
CURVE B: (24) IC61-E (A1)
CURVE C: (26) IC62-B (A1)
DEVICE TYPE: 54HC74 (DUAL D-TYPE F/F)
MFG: TIX 5 DEVICES TEST DATE 10-15-88
REF: JPL LOG 1374 DATE CODE 8801

PARAMETERS

CURVE A: (1) $10^4$ (A)
CURVE B: (2) $10^5$ (A)

DOSE, rads(Si) $^{60}$Co Gammas
0.5 rads/sec Dose Rate

TIME, hours
DEVICE TYPE: 54HC74 (DUAL D-TYPE F/F)
MFG: TIX 5 DEVICES TEST DATE 10-15-68
REF: JPL LOG 1374 DATE CODE 8601

PARAMETERS

CURVE A: (3) VTN(3)-ON (V)
CURVE B: (4) VTN(6)-ON (V)
CURVE C: (5) VTN(8)-OFF (V)
CURVE D: (6) VTN(11)-OFF (V)
DEVICE TYPE: 54HC74 (DUAL D-TYPE F/F)
MFG: TIX 5 DEVICES TEST DATE 10-15-88
REF: JPL LOG 1374 DATE CODE 8801

PARAMETERS

CURVE A: (7) VTP(3)-ON (V)
CURVE B: (8) VTP(6)-ON (V)
CURVE C: (9) VTP(8)-OFF (V)
CURVE D: (10) VTP(11)-OFF (V)

DOSE, rads(Si) Co$^{60}$ Gammas
0.5 rads/sec Dose Rate

TIME, hours

PRE-RAD 10$^3$ 1.5 2 3 4.5 6 1.5 1.5 10$^2$ 4.610$^2$ 4.610$^3$
DEVI CE TYPE: 54HC74 (DUAL D-TYPE F/F)
MFG: TIX 5 DEVICES TEST DATE 10-15-68
REF: JPL LOG 1374 DATE CODE 5601

PARAMETERS

CURVE A: (11) TPLH01 (S)
CURVE B: (12) TPHL01 (S)
CURVE C: (13) TPLH02 (S)
CURVE D: (14) TPHL02 (S)

DOSE, rads(Si) Co60 Gammas
0.5 rads/sec Dose Rate

TIME, hours

EOR

PRE-RAD

PARAMETER MEAN VALUE

0.100-08

1.100-08

1.212-08

1.325-08

1.437-08

1.550-08

1.662-08

1.775-08

1.887-08

2.000-08

1.101-03

1.500-03

2.000-03

3.000-03

4.000-03

5.000-03

6.000-03

10^2

4.610^2

4.610^3

4.610^4

10^3

PRE-10 3

ERROR
MEN VDH(V)

Dose, rads(Si) Co60 Gammas

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.060 1.063 2.063 3.063 5.063 7.063 1.064 1.564 2.064 2.564 3.064</td>
</tr>
<tr>
<td>STD.DEV.</td>
<td>.0028 .0022 .0026 .0026 .0029 .0040 .0072 .0176 .0334 .0312 .0374</td>
</tr>
</tbody>
</table>

| J0DC  | 4.9E4 |
| STD. DEV.| .0919 |

Initial mean value VDH(V) = +4.92x10^9
DEVICE TYPE: 54HC374 CMOS OCTAL D-TYPE IF

W76: NSC 3 DEVICES TEST DATE 11-13-85
DEF: JPL L38 1215 DATE CODE R6520

<table>
<thead>
<tr>
<th>DOSE, rads(Si)</th>
<th>Co60 Gammas</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0E0 1.9E3 2.0E3 3.0E3 5.0E3 7.0E3 1.0E4 1.5E4 2.0E4 2.3E4 3.0E4</td>
<td></td>
</tr>
<tr>
<td>3.5E4 3.7E4 6.1E4 2.2E4 3.2E4 5.9E4 9.7E4 6.7E4 1.0E5 1.3E5 19.6E4</td>
<td></td>
</tr>
<tr>
<td>4.0E4</td>
<td></td>
</tr>
<tr>
<td>63.26</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE: VOL(MV) = 41.52X10^2
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>DOSE</th>
<th>STD. DEV.</th>
<th>DOSE</th>
<th>STD. DEV.</th>
</tr>
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<tbody>
<tr>
<td>(3)</td>
<td></td>
<td>0.000</td>
<td>.0672</td>
<td>.000</td>
<td>2.063</td>
</tr>
<tr>
<td>ICH</td>
<td></td>
<td>1.0E3</td>
<td>.0760</td>
<td>1.0E4</td>
<td>.2191</td>
</tr>
<tr>
<td>IC</td>
<td></td>
<td>2.0E3</td>
<td>.0786</td>
<td>2.0E4</td>
<td>.5019</td>
</tr>
<tr>
<td>IC</td>
<td></td>
<td>3.0E3</td>
<td>.0772</td>
<td>2.5E4</td>
<td>.9302</td>
</tr>
<tr>
<td>IC</td>
<td></td>
<td>5.0E3</td>
<td>.0877</td>
<td>3.0E4</td>
<td>.8016</td>
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<tr>
<td>IC</td>
<td></td>
<td>7.0E3</td>
<td>.1290</td>
<td></td>
<td>.9459</td>
</tr>
<tr>
<td>IC</td>
<td></td>
<td>1.0E4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IC</td>
<td></td>
<td>1.5E4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IC</td>
<td></td>
<td>2.0E4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE ICH(MA) = -6.63x10^9
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE</th>
<th>Dose, rads(SI)</th>
<th>0.0E0</th>
<th>1.0E3</th>
<th>2.0E3</th>
<th>3.0E3</th>
<th>5.0E3</th>
<th>7.0E3</th>
<th>1.0E4</th>
<th>1.5E4</th>
<th>2.0E4</th>
<th>2.5E4</th>
<th>3.0E4</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>0.1513</td>
<td>0.1359</td>
<td>0.1442</td>
<td>0.1347</td>
<td>0.1396</td>
<td>0.1473</td>
<td>0.1916</td>
<td>0.2912</td>
<td>0.4325</td>
<td>0.5371</td>
<td>0.7346</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOL(MA) = 46.64X10^9
DEVICE TYPE: 54HC374 CMOS OCTAL D-TYPE FF
MFG: NSC 5 DEVICES TEST DATE 11-13-85
REF: JPL LOG 1215 DATE CODE R6520

DOSE, $\text{rads}(S\bar{I})$ $\text{Ca}^{60}$ Gammas

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE DOSE</th>
<th>DOSE, $\text{rads}(S\bar{I})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0E0</td>
<td>0.0000</td>
</tr>
<tr>
<td>1.0E3</td>
<td>0.0000</td>
</tr>
<tr>
<td>2.0E3</td>
<td>0.0000</td>
</tr>
<tr>
<td>3.0E3</td>
<td>0.0000</td>
</tr>
<tr>
<td>5.0E3</td>
<td>0.0000</td>
</tr>
<tr>
<td>7.0E3</td>
<td>0.0000</td>
</tr>
<tr>
<td>1.0E4</td>
<td>0.0000</td>
</tr>
<tr>
<td>1.5E4</td>
<td>0.0000</td>
</tr>
<tr>
<td>2.0E4</td>
<td>0.0000</td>
</tr>
<tr>
<td>2.5E4</td>
<td>0.0000</td>
</tr>
<tr>
<td>3.0E4</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE $\text{IIH}(\text{NA}) = +9.99 \times 10^{-1}$
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE:</td>
<td>0.0E0 1.0E3 2.0E3 3.0E3 5.0E3 7.0E3 1.0E4 1.5E4 2.0E4 2.5E4 3.0E4</td>
<td>.1789 .2608 .1414 .1673 .1673 .1095 .1789 .1673 .2280 .3847 .2000</td>
</tr>
<tr>
<td>DOSE</td>
<td>4.0E4</td>
<td>.2280</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IIl(NR) = +6.80x10⁻¹
DEVICE TYPE: 54HC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 8627

PARAMETERS CONDITIONS

CURVE A: 1) VOH1-A (V) 1) OUT = -20 UA
CURVE B: 2) VOH1-B (V) * *

PRE-RAD 5 6 7 10^4 1.5 2 3 4 5 6 10^5 2 4 2.2 4.4 10^2
DOSE, rads(Si) Co60 Gammas EOR TIME, hours

PARAMETER MEAN VALUE

[Graph showing parameter mean values over dose and time]
DEVICE TYPE: 5410374 OCTAL D-TYPE FIFO
MFG: NSC 3 DEVICES TEST DATE 3-24-67
REF: TPL LOG 1301 DATE CODE 8627

PARAMETERS

CURVE A: (3) VOH2-A (V)
CURVE B: (4) VOH2-B (V)

CONDITIONS

(OUT = -5.2 MA)
DEVICE TYPE: 54HC374 OCTAL D-TYPE FJF
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 6627

PARAMETERS

CURVE A: (5) VOL1-A (V) (IOUT = 20 UA)
CURVE B: (6) VOL1-B (V) " "
CURVE C: (7) VOL2-A (V) (IOUT = 5.2 MA)
CURVE D: (8) VOL2-B (V) " "

PRE-RAD DOSE, rads(Si) Co^{60} Gammas EOR TIME, hours

PARAMETER MEAN VALUE
DEVICE TYPE: 54HC374 OCTAL D-TYPE FF
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 3627

PARAMETER MEAN VALUE

DOSE, rads(Si) Co$^{60}$ Gammas EOR TIME, hours

PRE-RAD

CURVE A: [9] IiH-A (A) (VIN = VCC)
CURVE B: [10] IiH-B (A) * *
CURVE C: [11] IiL-A (A) (VIN = GND)
CURVE D: [12] IiL-B (A) * *

PARAMETERS CONDITIONS
DEVICE TYPE: 54HC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 8627

PARAMETERS

CURVE A: 102H1-A (A1) (VIN = 4.2 V)
CURVE B: 102H1-B (A1) *
CURVE C: 102H2-A (A1) (VIN = 1.2 V)
CURVE D: 102H2-B (A1) *

CONDITIONS

5-53
PARAMETERS CONDITIONS

CURVE A: (17) 10ZL1-A (A) (VIN = 4.2 V)
CURVE B: (16) 10ZL-B (A) " "
CURVE C: (19) 10ZL2-A (A) (VIN = 1.2 V)
CURVE D: (20) 10ZL2-B (A) " "

DOSE, rads(Si) Co\textsuperscript{60} Gammas TIME, hours

PARAMETER MEAN VALUE
DEVICE TYPE: 54HC374 OCTAL D-TYPE F/F
MANUFACTURER: NSC
DEVICES TESTED: 3
DATE: 3-24-87
REFERENCE: JPL LOG 1301
DATE CODE: 8627

PARAMETERS

CURVE A:  (21) ICCH-A  (A)
CURVE B:  (23) ICCL-A  (A)
CURVE C:  (25) ICCZ-A  (A)
PARAMETERS

CURVE A: (22) ICCH-B (A)
CURVE B: (23) ICCL-A (A)
CURVE C: (24) ICCL-B (A)
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AMD 2 DEVICES TEST DATE 04-09-86
REF: JPL LOG 1250 DATE CODE 8531EMM

PARAMETERS

CURVE A: (1) IIH (VIH=15V) IN NA:
PARAMETERS

CURVE A: (2) IIVL (VIL=OV) IN UA:
PARAMETERS

CURVE A: .51 [IFS3-IFS4] IN NA:
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AMD 2 DEVICES TEST DATE D4-09-86
REF: JPL LOG 1230 DATE CODE E3313MM

PARAMETERS

CURVE A: (6) PSS+1 (15V>VCC>4.5V, DELTA 10 MEASURED) IN NA:
CURVE B: (7) PSS+2 (15V>VCC>16V, DELTA 10 MEASURED IN NA:
CURVE C: (8) PSS-1 (-15V>VEE>-15V, DELTA 10 MEASURED) IN NA:
CURVE D: (9) PSS-2 (-15V>VEE>-16V, DELTA 10 MEASURED) IN NA:

DOS, rads(S): 2.5 MeV electrons

PARAMETERS

CURVE A: (6) PSS+1 (15V>VCC>4.5V, DELTA 10 MEASURED) IN NA:
CURVE B: (7) PSS+2 (15V>VCC>16V, DELTA 10 MEASURED IN NA:
CURVE C: (8) PSS-1 (-15V>VEE>-15V, DELTA 10 MEASURED) IN NA:
CURVE D: (9) PSS-2 (-15V>VEE>-16V, DELTA 10 MEASURED) IN NA:
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AMD  2 DEVICES  TEST DATE 04-09-86
REF: JPL L00 1230  DATE CODE 8531EMM

PARAMETERS

CURVE A:  (10) IREF (VREF=OV) IN NA:

Dose, rad(Si) 2.5 MeV electrons

Parameter Mean Value

Pre-Rad 10^4 1.5 2 3 4 5 6 10^5 1.5 2 3 4 5 6 10^6

1625.00

1432.94

1250.67

1156.61

936.75

764.07

572.62

420.56

-248.50

-4.20.56
DEVICE TYPE: AM6012A 12-BIT DAC

TYPE: AMD

2 DEVICES TEST DATE 04-09-86

REF: JPL L08 1250

DATE CODE 8531EHM

PARAMETERS

CURVE A: (11) NONLIN (MEAS'D DEV. FROM END-POINT CURVE FIT) IN FS:

5-63
PARAMETERS

CURVE A: (12) DNL+ (CALC. FROM MEAS'D BIT WEIGHTS IN TEST #46) FS:
CURVE B: (13) DNL- (CALC. FROM MEAS'D BIT WEIGHTS IN TEST #46) FS:
DEVICE TYPE: AM6012A 12-BIT DAC

MFG: AMD  2 DEVICES TEST DATE 04-09-86

REF: JPL LOG 1250  DATE CODE 8531LMM

PARAMETERS

CURVE A: (14) THIRL (MEAN 50 POINT TO 10(-) 50 POINT) IN NA:
PARAMETERS

CURVE A: (1) I0H (NA)
CURVE B: (2) I0L (NA)
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA  3 DEVICES  TEST DATE 09-15-86
REF: JPL LOG 1173  DATE CODE D407

PARAMETERS

CURVE A:  (3) VTN1-ON  (V)
CURVE B:  (4) VTN2-ON  (V)
CURVE C:  (7) VTN5-ON  (V)
CURVE D:  (6) VTN9-ON  (V)
PARAMETERS

CURVE A: (11) VTP1-OFF (V)
CURVE B: (12) VTP2-OFF (V)
CURVE C: (15) VTP6-OFF (V)
CURVE D: (16) VTP9-OFF (V)

DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-15-86
REF: JPL LOG 1173 DATE CODE D407

DOSE, rads(S.) Co\textsuperscript{60} Gammas
TIME, hours

PARAMETER MEAN VALUE
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCT 5 DEVICES TEST DATE 09-15-86
REF: JPL LOG 1173 DATE CODE D407

PARAMETERS

CURVE A: 137 VTP5-ON (V)
CURVE B: 141 VTP6-ON (V)
CURVE C: 137 VTP12-ON (V)
CURVE D: 136 VTP13-ON (V)

DOSAGE, rads(Si) Co60 Gammas TIME, hours

PARAMETER MEAN VALUE

-1.97 -1.95 -1.93 -1.91 -1.89 -1.87 -1.85 -1.83 -1.81 -1.79 -1.77 -1.75 -1.73 -1.71 -1.69 -1.67 -1.65 -1.63 -1.61 -1.59

-10^2 -1.5 2 3 4 5 6 10^3 1.5 2 3 4 5 6 10^4 1.5 2 3 4 5 6 10^5 1.5 2 3 4 5 6 10^6

-1.62 -1.64 -1.66 -1.68 -1.70 -1.72 -1.74

-10^2 10^3 10^4 10^5 10^6
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-15-86
REF: JPL LOG 1173 DATE CODE D407

PARAMETERS

CURVE A: (19) TR (NS)
CURVE B: (20) TR (NS)
PARAMETERS

CURVE A: (21) TPLH (NS)
CURVE B: (22) TPHL (NS)
PARAMETERS

CURVE A: (1) IQH IN NA:
CURVE B: (2) IQL IN NA:
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-86
REF: JPL Log 1203 DATE CODE D407

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>D</td>
<td>B</td>
</tr>
</tbody>
</table>

5-74
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-86
REF: JPL LOG 1203 DATE CODE D407

PARAMETERS CONDITIONS
CURVE A: (5) VTN 5-OFF (V) (BIAS GND)
CURVE B: (6) VTN 6-OFF (V) * *
CURVE C: (9) VTN12-OFF (V) * *
CURVE D: (10) VTN13-OFF (V) * *

DOSE, rads(Si) Co \textsuperscript{60} Gammas
TIME, hours

PARAMETER MEAN VALUE

PRE-RAD 10\textsuperscript{-4} 1.5 2. 3. 4. 5. 6. 10\textsuperscript{4} 10\textsuperscript{5}

EOP

10\textsuperscript{2} 2. 4.6 \times 10\textsuperscript{2} 2. 4.6 \times 10\textsuperscript{2} 2.
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-66
REF: TPL LOG 1203 DATE CODE D407

PARAMETERS CONDITIONS

| CURVE A: (11) VTP 1-OFF (V)  |
| CURVE B: (12) VTP 2-OFF (V)  |
| CURVE C: (15) VTP 8-OFF (V)  |
| CURVE D: (16) VTP 9-OFF (V)  | (BIAS 15V) |

5-76
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-86
REF: JPL LOG 1203 DATE CODE D407

PARAMETERS
CURVE A: (13) VTP 5-ON (V)
CURVE B: (14) VTP 6-ON (V)
CURVE C: (17) VTP12-ON (V)
CURVE D: (18) VTP13-ON (V)

CONDITIONS
(E/BIAS GND)
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-86
REF: JPL LOG 1203 DATE CODE D407

PARAMETERS
CURVE A: (19) TR IN NS:
CURVE B: (20) TF IN NS:
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-86
REF: JPL LOG 1203 DATE CODE D407

PARAMETERS
CURVE A: (21) TPLH IN NS:
CURVE B: (22) TPLH IN NS:
DEVICE TYPE: CD4013 CMOS DUAL D FF
MFG: SGS 5 DEVICES TEST DATE 06-22-85
REF: JPL LAB 1176 DATE CODE 332V

DEVICE TYPE: CD4013 CMOS DUAL D FF
MFG: SGS 5 DEVICES TEST DATE 06-22-85
REF: JPL LAB 1176 DATE CODE 332V

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rad(Si) Co60 Gammas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>0.963 1.063 2.635 3.063 1.064 2.064 3.064 5.064 1.063</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>.9998 .2770 .2345 .2596 7.456 479.4 3272. 9417. XXXXX</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOH(UA) = +2.13X10^3
DEVICE TYPE: CD4013 CMOS DUAL D FF
MFG: SGS  5 DEVICES  TEST DATE 06-22-85
REF: TPL 108 1176  DATE CODE 352V

DOSE, rads(S:), Co$^{60}$ Gammas
(VDD=15V) IN UA VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S:)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2)10L</td>
<td>0.0001 1.0E3 2.0E3 5.0E3 1.0E4 2.0E4 3.0E4 5.0E4 1.0E5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>.0665 .1636 .1561 .2874 7.621 176.1 1102. 5267. 1572.</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOL(UA) = +1.05X10^8

5-81
DEVICE TYPE: CD4013 CMOS DUAL DFF
MFG: 868 5 DEVICES TEST DATE 06-22-65
REF: JPL LOG 1176 DATE CODE 352Y

DOS: rads(S.) Co60 Gammas

(3) V.OH02 (10=6.6m) IN V VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOS (rads)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5E-3 1.0E-3 2.0E-3 5.0E-3 1.0E4 2.0E4 3.0E4 5.0E4 1.0E5</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>0.0418 0.0447 0.0570 0.0652 0.0447 0.0570 0.2162 0.6544 XXXX</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE V.OH02(V) = +1.36X10^5
DEVICE TYPE: CD4013 CMOS DUAL D/F/F

RF#: 888  5 DEVICES  TEST DATE 06-22-85

REF: JPL LOG 1176  DATE CODE 352V

---

**TABLE OF NORMAL STANDARD DEVIATIONS**

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose 1</td>
<td>0.000</td>
<td>.3365</td>
</tr>
<tr>
<td>Dose 2</td>
<td>0.003</td>
<td>1.003</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOH02(MA) = -7.01X10^4
**DEVICE TYPE:** CD4013 CMOS DUAL D FF

**MFG:** SGS  5 DEVICES  TEST DATE 06-22-85

**REF:** JPL LOG 1176  DATE CODE 352V

---

**Dose, rads(Si) Co60 Gammas**

(5) VOL02 (10:50UA) IN MV: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>0.9E0 1.0E3 2.1E3 5.0E3 1.0E4 2.0E4 3.0E4 5.0E4 1.0E5</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>2706 .2987 .5910 .4077 .1255 .4791 .5387 2.0E5 2.536</td>
</tr>
</tbody>
</table>

**Initial mean value VOL02(MV) = +7.67x10⁻⁴**

---

**GRAPH:**

- **X-axis:** PPE RAD
- **Y-axis:** MEAN VOL02(MV)
- **Title:** Dose, rads(Si) Co60 Gammas
- **Data Points:**
  - (5) VOL02 (10:50UA) IN MV: VS DOSE

---

**5-84**
DEVICE TYPE: CD4013 CMOS DUAL D FF
MFG: SGS 5 DEVICES TEST DATE 06-22-85
REF: JPL L06 1176 DATE CODE 352Y

DOSE, rads(Si) Co^60 Gammas
(6)1L02 (VQ=1.5V) IN MA: V8 DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.0E0 1.0E3 2.1E3 5.0E3 1.0E4 2.0E4 3.0E4 5.0E4 1.0E5</td>
<td>2359 .2301 .2272 .2450 .1717 .1769 .1460 .3657 .4016</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOL02(MA) = +6.59X10^12

* DEVICE PARAMETER FAILURE

5-85
DEVEICE TYPE: CD4013 DUAL D $1$F
MFG: SGS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1204 DATE CODE 352V

PARAMETERS

CURVE A: (1) I0H(NA)
CURVE B: (2) I0L(INA)

DOSE, rads(Si) Co$^{60}$ Gammas
TIME, hours

PARAMETER MEAN VALUE
DEVICE TYPE: CD4013 DUAL D FF
MFG: SGS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1204  DATE CODE 352V

PARAMETERS

CURVE A: (3) VTN3-ON (V)
CURVE B: (5) VTN5-ON (V)
CURVE C: (6) VTN6-ON (V)
CURVE D: (9) VTN10-ON (V)

*ANNEAL
DEVI C E  T Y P E :  CD4013 DU A L D FI F
MFG:  SGS  5 DEVICES TEST DATE 10-29-66
PREF:  JPL LOG 1204 DATE CODE 352V

PARAMETERS

CURVE A:  (4) VTN4-OFF  (V)
CURVE B:  (7) VTN8-OFF  (V)
CURVE C:  (6) VTN9-OFF  (V)
CURVE D:  (10) VTN13-OFF  (V)
PARAMETERS

CURVE A: (19) TFQ1(NS)
CURVE B: (20) TFQ2(NS)
CURVE C: (21) TRQ1(NS)
CURVE D: (22) TRQ2(NS)
DEVICE TYPE: CD4013 DUAL D F/F
MFG: SGS 3 DEVICES TEST DATE 10-20-66
REF: JPL LOG 1204 DATE CODE 352Y

PARAMETERS
CURVE A: (23)TPLH01(NS)
CURVE B: (24)TPLH02(NS)
CURVE C: (25)TPHL01(NS)
CURVE D: (26)TPHL02(NS)
PARAMETERS

CURVE A: (1)IQH(NR)
CURVE B: (2)QL(NR)

* ACCELERATED ANNEAL
DEVICE TYPE: CD4013 DUAL D CIF.
MFG: SSI 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1267 DATE CODE 8321

PARAMETERS
CURVE A: (3) VTN3-ON (V)
CURVE B: (5) VTN5-ON (V)
CURVE C: (6) VTN6-ON (V)
CURVE D: (9) VTN10-ON (V)
DEVICE TYPE: CD4013 DUAL D FF
MFG: SSS  5 DEVICES  TEST DATE 10-29-86
REF: JPL LOG 1267  DATE CODE 8321

PARAMETERS

CURVE A: 1 VTN4-OFF (V)
CURVE B: 7 VTN8-OFF (V)
CURVE C: 8 VTN9-OFF (V)
CURVE D: 10 VTN11-OFF (V)

DOS, rads(Si) Co60 Gammas
TIME, hours
DEVICE TYPE: CD4013 DUAL D F/F
MFG: SS8 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1267 DATE CODE 8321

PARAMETERS
CURVE A: (19)TFQ1(NS)
CURVE B: (20)TFQ2(NS)
CURVE C: (21)TRQ1(NS)
CURVE D: (22)TRQ2(NS)
DEVICE TYPE: CD4013 DUAL D FF
MFG: SSS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1267 DATE CODE 8321

PARAMETERS
CURVE A: (23) TPLHQ1 (NS)
CURVE B: (24) TPLHQ2 (NS)
CURVE C: (25) TPHLQ3 (NS)
CURVE D: (26) TPHLQ2 (NS)
DEVICE TYPE: CD4013 DUAL D F/F
MFG: SSS 5 DEVICES  TEST DATE 10-29-86
REF: IPL LOG 1268    DATE CODE 8321

PARAMETERS
CURVE A: (SJ): R(H(N))
CURVE B: (2)IQ(N(N))
DEVICE TYPE: CD4013 DUAL D FF
MFG: SSS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1268 DATE CODE 8321

PARAMETER MEAN VALUE

DOSE, rads(Si) Co60 Gammas

EOP

TIME, hours

PARAMETERS

CURVE A: (3) VTN3-ON (VI)
CURVE B: (5) VTN5-ON (VI)
CURVE C: (6) VTN6-ON (VI)
CURVE D: (9) VTN19-ON (VI)
PARAMETERS

CURVE A: (4) VTN4-OFF (V)
CURVE B: (7) VTN8-OFF (V)
CURVE C: (6) VTN9-OFF (V)
CURVE D: (10) VTN11-OFF (V)
DEVICE TYPE: CD4013 DUAL D Flip-Flop
MFG: SSS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1268 DATE CODE 8321

PARAMETERS

CURVE A: (191TFQ)(NS)
CURVE B: (201TFQ2)(NS)
CURVE C: (211TAQ)(NS)
CURVE D: (221TAQ2)(NS)
PARAMETERS

CURVE A: (23)TPLH01(NS)
CURVE B: (24)TPLH02(NS)
CURVE C: (25)TPLH01(NS)
CURVE D: (26)TPLH02(NS)
DEVICE TYPE: HCF4007 INVERTER
MFG: 866 4 DEVICES TEST DATE 09-13-88
REF: JPL LOG 1378 DATE CODE 98822Y

PARAMETERS

CURVE A: (1) IDSNO(6)-ON (A)
CURVE B: (2) IDSNO(6)-OFF (A)
CURVE C: (3) IDSNO(10)-ON (A)

DOSE, rads(Si) Co60 Gammas
20 rads/sec Dose Rate
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 09-13-86
REF: JPL LOB 1376 DATE CODE 98822Y

DOSE, rads(Si) Co\(^{60}\) Gammas
20 rads/sec Dose Rate

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DSP Configuration</th>
<th>COMMENTS</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>(4) DSP(6)-OFF</td>
<td>(A)</td>
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<td>B</td>
<td>(5) DSP(6)-ON</td>
<td>(A)</td>
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<tr>
<td>C</td>
<td>(6) DSP(10)-OFF</td>
<td>(A)</td>
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</tbody>
</table>
DEVELOPMENT 5-103

DEVICE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 09-13-88
REF: JPL LOG 1378 DATE CODE 988224

PARAMETERS
CURVE A: [7] VTN(6)-ON (V)
CURVE B: [8] VTN(3)-OFF (V)
CURVE C: [9] VTP(10)-ON (V)

DOSE, rads(S/Co) Co60 Gamma
20 rads/sec Dose Rate
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS  4 DEVICES TEST DATE 09-13-86
REF: JPL LOG 1316  DATE CODE 96822Y

PARAMETERS

CURVE A:  (10) VTP(6)-OFF (V)
CURVE B:  (11) VTP(3)-ON (V)
CURVE C:  (12) VTP(10)-OFF (V)

DOSE, rads(Si) Co\textsuperscript{60} Gammas
20 rads/sec Dose Rate
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 09-15-88
REF: JPL LOS 1379 DATE CODE 98822Y

DOSE, rads(Si) Co\textsuperscript{60} Gammas
0.5 rads/sec Dose Rate

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IDSN</th>
<th>PARAMETER</th>
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<tbody>
<tr>
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<tr>
<td>B</td>
<td>3</td>
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<tr>
<td>C</td>
<td>101</td>
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</table>
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 09-15-86
REF: JPL LOG 1379 DATE CODE 96622Y

DOSE, rads(Si) Co60 Gammas
0.5 rads/sec Dose Rate

PARAMETERS
CURVE A: (4) DSP(6)-OFF (A)
CURVE B: (5) DSP(3)-ON (A)
CURVE C: (6) DSP(10)-OFF (A)
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS  4 DEVICES  TEST DATE 09-15-88
REF: JPL 108 1379  DATE CODE 96822Y

DOSE, rads(Si) Co\(^{60}\) Gammas
0.5 rads/sec Dose Rate

PARAMETERS

CURVE A: (7) VTN(6)-ON (V)
CURVE B: (8) VTN(3)-OFF (V)
CURVE C: (9) VTP(10)-ON (V)
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS
4 DEVICES
TEST DATE 09-15-88
REF: JPL LOG 1379
DATE CODE 96822Y

DOSE, rads(Si) Co60 Gammas
0.5 rads/sec Dose Rate

PARAMETERS
CURVE A: VTP(6)-OFF (V)
CURVE B: VTP(3)-ON (V)
CURVE C: VTP(10)-OFF (V)
PARAMETERS

CURVE A:  (1) IDSN(6)--ON  (A)
CURVE B:  (2) IDSN(3)--OFF  (A)
CURVE C:  (3) IDSN(10)--ON  (A)
PARAMETERS

CURVE A:  (4)  [DSP(6)]-OFF  (A)
CURVE B:  (5)  [DSP(3)]-ON  (A)
CURVE C:  (6)  [DSP(10)]-OFF  (A)
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS  4 DEVICES  TEST DATE 09-19-86
REF: JPL L08 1360  DATE CODE 96822Y

PARAMETERS

CURVE A: 0.1 VTN(6)-ON (V)
CURVE B: 0.8 VTN(3)-OFF (V)
CURVE C: 0.9 VTP(10)-ON (V)
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 09-19-86
REF: JPL LOC 1360 DATE CODE 96C22Y

PARAMETERS
CURVE A: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF(V)
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 09-19-68
REF: JPL L06 1368 DATE CODE 966229

PARAMETERS

CURVE A: (1) IDSN(1)-ON (A)
CURVE B: (2) IDSN(3)-OFF (A)
CURVE C: (3) IDSN(10)-ON (A)

DOSE, rads(Si) Co$^{60}$ Gammas
20 rads/sec Dose Rate

PARAMETER MEAN VALUE

PRE- RAD 10$^3$ 1.5 2 3 4 5 6

DOSERATE 10$^{-10}$ 10$^{-9}$ 10$^{-8}$ 10$^{-7}$ 10$^{-6}$ 10$^{-5}$ 10$^{-4}$ 10$^{-3}$
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS  4 DEVICES TEST DATE 09-19-88
REF: JPL L08 1366 DATE CODE 98822Y

PARAMETERS
CURVE A:  (4) IDSP(6)-OFF (A)
CURVE B:  (5) IDSP(3)-ON  (A)
CURVE C:  (6) IDSP(10)-OFF (A)
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES  TEST DATE 09-19-88
REF: JPL LOG 1388  DATE CODE 96622Y

DOSE, rads(SI) Co$^{60}$ Gammas
20 rads/sec Dose Rate

PARAMETERS
CURVE A: (7) VTN(6)-ON (V)
CURVE B: (8) VTN(3)-OFF (V)
CURVE C: (9) VTP(10)-ON (V)
DEVICE TYPE: HCF40D7 INVERTER
MFG: SBS 4 DEVICES TEST DATE 09-19-88
REF: JPL LOG 1366 DATE CODE 96622Y

DOSE, rads(S.) Co\textsuperscript{60} Gammas
20 rads/sec Dose Rate

PARAMETERS

CURVE A: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF (V)
DEVICE TYPE: 4CF4007 INVERTER
MFG: 98S 4 DEVICES TEST DATE 10-03-86
REF: JPL LO8 1369 DATE CODE 96622Y

DOSE, rads(Si) Co^{60} Gammas
0.0116 rads/sec Dose Rate

PARAMETERS

CURVE A: (1) IDSN[6]-ON (A)
CURVE B: (2) IDSN[3]-OFF (A)
CURVE C: (3) IDSN[10]-ON (A)
DEVICE TYPE: HF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 10-03-88
REF: JPL L08 1389 DATE CODE 98622Y

PARAMETERS

CURVE A: (4) IDSP(6)-OFF (A1)
CURVE B: (5) IDSP(3)-ON (A1)
CURVE C: (6) IDSP(10)-OFF (A1)
DEVICE TYPE: HCF4007 INVERTER
MFG: S88 4 DEVICES TEST DATE 10-03-88
REF: JPL L081389 DATE CODE 98822Y

DOSE, rads(Si) Co$^{60}$ Gammas
0.0116 rads/sec Dose Rate

PARAMETERS

CURVE A: (7) VTN(6)-ON (V)
CURVE B: (8) VTN(3)-OFF (V)
CURVE C: (9) VTP(10)-ON (V)
DEVI CE TYPE: HCF4007 INVERTER
MF6: SBS  4 DEVICES    TEST DATE 10-03-88
REF: JPL LOG 1369   DATE CODE 98622Y

DOSE, rads(Si) Co60 Gammas
0.0116 rads/sec Dose Rate

PARAMETERS
CURVE A: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF (V)
DEVICE TYPE: HCF4007 INVERTER
MFG: 988  4 DEVICES  TEST DATE 10-10-88
REF: JPL L08 1390  DATE CODE 96622Y

DOSE, rads(Si) Co$^{60}$ Gammas
0.0058 rads/sec Dose Rate

PARAMETERS

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<thead>
<tr>
<th>CURVE</th>
<th>IDSN Code</th>
<th>Status</th>
<th>(Ref)</th>
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<tr>
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<td>(1)</td>
<td>OFF</td>
<td>(A)</td>
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<tr>
<td>B</td>
<td>(2)</td>
<td>OFF</td>
<td>(A)</td>
</tr>
<tr>
<td>C</td>
<td>(3)</td>
<td>ON</td>
<td>(A)</td>
</tr>
</tbody>
</table>
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 10-10-88
REF: JPL LOG 1390 DATE CODE 98822Y

DOSE, rads(S) Co\textsuperscript{60} Gammas
0.0058 rads/sec Dose Rate

PARAMETERS
CURVE A: (7) VTN(6)-ON (V)
CURVE B: (8) VTN(3)-OFF (V)
CURVE C: (9) VTP(10)-ON (V)

5-123
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 10-10-88
REF: JPL L08 1390 DATE CODE 96622Y

PARAMETERS

CURVE A: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF (V)
PARAMETERS

CURVE A:  (1) IQH  (A)
CURVE B:  (2) IQL  (A)
DEVICE TYPE: HC4013 DUAL D-TYPE F1F
MFG: SGS 6 DEVICES TEST DATE 07-19-68
REF: JPL LOG 1360 DATE CODE 98814V

PARAMETERS

CURVE A: (3) VTN(3)-ON (V)
CURVE B: (5) VTN(5)-ON (V)
CURVE C: (6) VTN(6)-ON (V)
CURVE D: (9) VTN(10)-ON (V)

DOSE, rads(Si) Co60 Gammas
1.0 rads/sec Dose Rate

CURVE A
CURVE B
CURVE C
CURVE D

PARAMETERS

CURVE A: (3) VTN(3)-ON (V)
CURVE B: (5) VTN(5)-ON (V)
CURVE C: (6) VTN(6)-ON (V)
CURVE D: (9) VTN(10)-ON (V)

5-126
DEVICE TYPE: HOF4013 DUAL D-TYPE F/F
MFG: SGS 6 DEVICES TEST DATE 07-19-88
REF: JPL LOG 1360 DATE CODE 96814Y

PARAMETERS

CURVE A: (4) VTN(4) -- OFF (V)
CURVE B: (7) VTN(7) -- OFF (V)
CURVE C: (8) VTN(9) -- OFF (V)
CURVE D: (10) VTN(10) -- OFF (V)

DOSE, rads(Si) Co^{60} Gammas
1.0 rads/sec Dose Rate

TIME, hours
DEVICE TYPE: 40F4013  DUAL D-TYPE F/F
MFG: SGS & DEVICES  TEST DATE 07-19-86
REF: TPL LOG 1360  DATE CODE 96E14Y

PARAMETERS

CURVE A: TPLH41 (S)
CURVE B: TPLH41 (S)
CURVE C: TPLH42 (S)
CURVE D: TPLH42 (S)

DOSE, rads(S): Co60 Gammas
1.0 rads/sec Dose Rate

PRE-RAD  10^3  1.5  2.  3.  4.  5.  6.  10^4 10^5 10^6

EOR  10^3  10^4 10^5 10^6 10^7 10^8

TIME, hours

PARAMETERS:
CURVE A: TPLH41 (S)
CURVE B: TPLH41 (S)
CURVE C: TPLH42 (S)
CURVE D: TPLH42 (S)

5-128
DEVICE TYPE: HCF4013  DUAL D-TYPE F1F
MFG: SGS  6 DEVICES  TEST DATE 06-06-88
REF: JPL LOG 1364  DATE CODE 96614Y

PARAMETER MEAN VALUE

DOSE, rads(Si) Co^{60} Gammas
0.5 rads/sec Dose Rate

TIME, hours

PARAMETERS

CURVE A:  (1) IQH  (A)
CURVE B:  (2) IQL  (A)
PARAMETERS

CURVE A: (3) VTN(3)-ON (V)
CURVE B: (4) VTN(6)-ON (V)
CURVE C: (5) VTN(8)-OFF (V)
CURVE D: (6) VTN(11)-OFF (V)
PARAMETERS

CURVE A: (1) IQH(NA)
CURVE B: (2) IQL(NA)
DEVICE TYPE: HCFL53BE DUAL D FF

MTB: 66S 5 DEVICES TEST DATE 9-25-66

PET: JPL LAB 1467 DATE CODE 3527

PARAMETERS

CURVE A: (V) VIN2-ON
CURVE B: (V) VIN5-ON
CURVE C: (V) VINK-ON
CURVE D: (V) VIN30-ON

DOSE, rads(S.) Co60 Gammas

PARAMETER MEAN VALUE

PPE - PAD

D-132
PARAMETERS

CURVE A:  VTN4-OFF (V)
CURVE B:  VTN8-OFF (V)
CURVE C:  VTN9-OFF (V)
CURVE D:  VTN11-OFF (V)
DEVICE TYPE: HCF4013BE DUAL D FF

MFG: SBS 3 DEVICES TEST DATE 9-25-86

REF: JPL LOG 1177 DATE CODE 352Y

PARAMETERS

CURVE A: (13) VIP3-OFF (V)
CURVE B: (13) VIP5-OFF (V)
CURVE C: (14) VIP6-OFF (V)
CURVE D: (17) VIP20-OFF (V)
DEVICE TYPE: HC4013BE DUAL D'IF
MFG: S68 5 DEVICES TEST DATE 9-28-86
REF: JPL L08 1J7 DATE CODE 352Y

PARAMETERS

CURVE A: (12) VTP4-ON (V)
CURVE B: (15) VTP8-ON (V)
CURVE C: (16) VTP9-ON (V)
CURVE D: (18) VTP12-ON (V)

5-135
PARAMETERS

CURVE A: (19)TF1(NS)
CURVE B: (20)TF2(NS)
CURVE C: (21)TR1(NS)
CURVE D: (22)TR2(NS)
DEVICE TYPE: HG4013BE DUAL D F/F
MFG: SBS  3 DEVICES  TEST DATE 9-25-66
REF: JPL LOG 1177  DATE CODE 352Y

PARAMETERS
CURVE A: (23) TPLH1(NS)
CURVE B: (24) TPLH2(NS)
CURVE C: (25) TPHL1(NS)
CURVE D: (26) TPHL2(NS)
DEVICE TYPE: HCF4013BE DUAL D F/F
MFG: 968 5 DEVICES TEST DATE 9-23-86
REF: JPL LOG 1178 DATE CODE 332Y

PARAMETERS

CURVE A: (1)IQH(NA)
CURVE B: (2)IQL(NA)
DEVELOPE TYPE: HC401JBE DUAL D F/F
MFG: SBS 5 DEVICES TEST DATE 9-25-86
REF: JPL LOB 1176 DATE CODE 352Y

PARAMETERS
CURVE A: (3) VTN3-ON (V)
CURVE B: (5) VTN5-ON (V)
CURVE C: (6) VTN6-ON (V)
CURVE D: (9) VTN10-ON (V)
DEVICE TYPE: 4CF4013BE DUAL D F/F
MFG: SGS 3 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1176 DATE CODE 352Y

PARAMETERS

CURVE A: (4) VTN4-OFF (V)
CURVE B: (7) VTN8-OFF (V)
CURVE C: (8) VTN9-OFF (V)
CURVE D: (10) VTN11-OFF (V)
PARAMETERS

CURVE A: (11) VTP3-OFF (V)
CURVE B: (13) VTP5-OFF (V)
CURVE C: (14) VTP6-OFF (V)
CURVE D: (17) VTP10-OFF (V)
DEVICE TYPE: HCF4013BE DUAL D'F/F
MFG: SGS 5 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1178 DATE CODE 352Y

PARAMETERS
CURVE A: (12) VTP4-ON (V)
CURVE B: (15) VTP8-ON (V)
CURVE C: (16) VTP9-ON (V)
CURVE D: (18) VTP11-ON (V)

Dose, rood(Si) Co^{60} Gammas

Parameter Mean Value

PRE-RAD

10^2  1.5  2.  3  4  5  6  10^3  1.5  2  3  4  5  6
PARAMETERS

CURVE A: 191TF1(NS)
CURVE B: 201TF2(NS)
CURVE C: 211TR1(NS)
CURVE D: 221TR2(NS)
DEVICE TYPE: HCF4013BE DUAL D FF
MFG: SGS 9 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1178 DATE CODE 352Y

PARAMETERS

CURVE A: (23)TPLA1(NS)
CURVE B: (24)TPLA2(NS)
CURVE C: (25)TPHL1(NS)
CURVE D: (26)TPHL2(NS)
DEVICE TYPE: LF356BH FET INPUT OP AMP
MFG: NSC 3 DEVICES TEST DATE 12-06-85
REF: JPL L08 1168 DATE CODE H6448

DOSE, rads(Si) Co\textsuperscript{60} Gammas

(1) VOS (RS=50 OHMS) IN MV: VS DOSE

<table>
<thead>
<tr>
<th>TABLE OF NORMAL STANDARD DEVIATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURVE</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>DOSE</td>
</tr>
<tr>
<td>STD.</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOS(MV) = -6.63x10\textsuperscript{-3}
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S; 1) Co60 Gammas</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.9E0 1.9E4 2.9E4 3.9E4 5.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6</td>
<td>.0007 .0006 .0042 .0145 .0165 .0943 16.67 31.07 118.6 31.90</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE I0S(NA) = +3.79x10^-4
DEVICE TYPE: LF336BH FET INPUT OP AMP
MFG: NEC  3 DEVICES  TEST DATE 12-06-85
REF: JPL LOG 1168  DATE CODE H6448

**TABLE OF NORMAL STANDARD DEVIATIONS**

<table>
<thead>
<tr>
<th>DOSE, rads(Si) Co^{60} Gammas</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0E-6</td>
<td>1.0E-4</td>
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<tr>
<td>STD. DEV.</td>
<td>.0025</td>
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</table>

INITIAL MEAN VALUE IB(INIA) = 4.76x10^{-2}
DEVICE TYPE: LF356BH FET INPUT OP AMP
MFG: NSC 3 DEVICES TEST DATE 12-06-85
REF: JPL LOG 1168 DATE CODE HE448

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rods(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
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<td></td>
</tr>
<tr>
<td>0.9E4</td>
<td>2.516 2.591 2.054 4.762 2.035 2.687 3.675 30.06 11.69</td>
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</tr>
</tbody>
</table>

INITIAL MEAN VALUE (GAIN/db) = +1.35E-02

5-148
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE</th>
<th>STD. DEV.</th>
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</thead>
<tbody>
<tr>
<td>0.2E3</td>
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<tr>
<td>1.0E4</td>
<td>2.261</td>
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<tr>
<td>2.0E4</td>
<td>2.517</td>
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<td>3.0E4</td>
<td>2.232</td>
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<td>5.0E4</td>
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<td>2.395</td>
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<td>3.0E5</td>
<td>16.33</td>
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<td>6.0E5</td>
<td>34.37</td>
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<tr>
<td>1.0E6</td>
<td>17.06</td>
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</table>

INITIAL MEAN VALUE - GAIN(DB) = 41.33X10^2
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>(\Delta V_{OS} (MV))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.0E4 2.0E4 3.0E4 5.0E4 7.5E4</td>
<td>0.0163 0.0407 0.0911 1.209 1.969</td>
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</tbody>
</table>
DEVICE TYPE: LF 356BH OP AMP
MFG: NSC 4 DEVICES TEST DATE 09-30-85
REF: JPL LOG 1169 DATE CODE H8448

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S;) Co60 Gammas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>.1134 .1526 .0844 .0776 .201</td>
</tr>
</tbody>
</table>

DOSE, rads(S;) Co60 Gammas

MEAN ΔDOS(NA) X 10^-2

5-151
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>CO60 Gammas</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
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<td>.2334 .2654 .2676 .4505</td>
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</table>
TABLE OF NORMAL STANDARO DEVIATIONS

<table>
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<th>L_0</th>
<th>DOSE, rads(Si) Co^{60} Gammas</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>D</td>
<td>1.9e4</td>
<td>3.276 2.769 3.706 2.207 2.997</td>
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</tbody>
</table>

INITIAL MEAN VALUE +GAIN(DB) = 1.5x10^2
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Dose, rad(S/1)</th>
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<tbody>
<tr>
<td>I</td>
<td>1.0E4 2.0E4 3.0E4 5.0E4 7.5E4</td>
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<tr>
<td>C</td>
<td>1.0E 4.024 3.676 3.225 3.327 3.162</td>
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</table>

INITIAL MEAN VALUE -GAIN(DB) = 1.23X10^4
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-63
REF: JPL LOG 1150 DATE CODE 6437

DOSE, rads(Si) Co^{60} Gammas
(1)VOS (RS=50 OHMS) IN MV VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>DOSE</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.0E2</td>
<td>1.0E4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0242</td>
<td>0.0281</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOS(MV) = -1.26 \times 10^{-2}
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0E0</td>
<td>21.07</td>
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<tr>
<td>dos(50)</td>
<td>1.0E1</td>
<td>66.58</td>
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<tr>
<td></td>
<td>2.0E1</td>
<td>93.39</td>
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<tr>
<td></td>
<td>3.0E1</td>
<td>258.6</td>
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<tr>
<td></td>
<td>5.0E1</td>
<td>9757.0</td>
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</table>

INITIAL MEAN VALUE I0S(PA) = -1.89x10^4
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-85
REF: JPL LOG 1130 DATE CODE 8437

![Graph showing the relationship between dose and mean 121632(pA).]

<table>
<thead>
<tr>
<th>DOSE, rads(Si)</th>
<th>0.2E4</th>
<th>1.0E4</th>
<th>2.0E4</th>
<th>3.0E4</th>
<th>5.0E4</th>
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<tr>
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<td>30.51</td>
<td>41.31</td>
<td>65.17</td>
<td>197.1</td>
<td>4843</td>
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</table>

INITIAL MEAN VALUE 121632(pA) = +6.21X10^2

5-157
DEVICE TYPE: LT1012 OP AMP
MFG: LTC
4 DEVICES
TEST DATE 12-16-85
REF: JPL LOG 1150
DATE CODE 8437

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si): Co\textsuperscript{60} Gammas</th>
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<tbody>
<tr>
<td>Dose</td>
<td>0.0E0 1.0E4 2.0E4 3.0E4 5.0E4</td>
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<td>3.261 11.06 12.06 1.160 2.466</td>
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INITIAL MEAN VALUE +GAIN(DB) = +7.35X10\textsuperscript{4}
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-85
REF: JPL LUB 1150 DATE CODE 6437

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S)</th>
<th>Co²⁰ Gammas</th>
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<tr>
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<td>0.0E0 1.0E4 2.0E4 3.0E4 5.0E4</td>
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<td>1.736 2.322 7.476 .7661 .7135</td>
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INITIAL MEAN VALUE -GAIN(DB) = ±5.45X10⁻¹
DEVICE TYPE: MC14007 D COMPLIMENTARY W/INVER
MFG: MOT 6 DEVICES TEST DATE 09-07-86
REF: JPL LOG 1376 DATE CODE FR 8705

0.5 rads/sec Dose Rate

PARAMETERS
CURVE A: (1) IDSN(6)-ON (A)
CURVE B: (2) IDSN(3)-OFF (A)
CURVE C: (3) IDSN(10)-ON (A)
DEVICE TYPE: MC14007 D COMPLIMENTARY W/INVER
MFG: MOT 6 DEVICES TEST DATE 09-07-86
REF: JPL LOG 1376 DATE CODE FR 8705

PARAMETERS
CURVE A: (4) IDSP(6)-OFF (A)
CURVE B: (5) IDSP(3)-ON (A)
CURVE C: (6) IDSP(10)-OFF (A)

DOSE, rads(S;) Co60 Gammas
0.5 rads/sec Dose Rate

TIME, hours

PARAMETER MEAN VALUE

PRE-RAD 10^3 1.5 2 3 4 5 6 10^4 1.5 2 10^3 EOR 4.610^3 4.610^2 4.610^1 4.610^0
DETEC TYPE: MCI4007D COMPLIMENTARY W/JINVER
MFG: MOT 6 DEVICES TEST DATE 09-07-86
REF: JPL LOG 1376 DATE CODE FR 8705

PARAMETERS
CURVE A: (7) VTN(6)-ON (V)
CURVE B: (8) VTN(3)-OFF (V)
CURVE C: (9) VTP(10)-ON (V)
DEVICE TYPE: MC14007 D COMPLEMENTARY W/JNVER
MFG: MCT  6 DEVICES  TEST DATE 09-07-88
REF: JPL LOG 1376  DATE CODE FR 8705

PARAMETERS
CURVE A: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF (V)

DOSE, rads(Si) Co$^{60}$ Gammas
0.5 rads/sec Dose Rate

TIME, hours

PARAMETER MEAN VALUE

PRE-RAD

10$^3$  1.5  2  3  4  5  6  6.10$^4$  1.5

5-163
DEVICE TYPE: MC14007 D COMPLIMENTARY W/JINVER
MFG: MOT 6 DEVICES TEST DATE 06-17-86
REF: JPL LOG 1377 DATE CODE FR 8705

PARAMETER MEAN VALUE

DOSE, rads(Si) Co\textsuperscript{60} Gammas

TIME, hours

20 rads/sec Dose Rate

PARAMETERS

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<tr>
<th>CURVE</th>
<th>PARAMETER</th>
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<tbody>
<tr>
<td>A</td>
<td>IDS\textsuperscript{(6)}-ON (A)</td>
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<tr>
<td>B</td>
<td>IDS\textsuperscript{(3)}-OFF (A)</td>
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<tr>
<td>C</td>
<td>IDS\textsuperscript{(10)}-ON (A)</td>
</tr>
</tbody>
</table>
DEVICE TYPE: MC14007 D COMPLEMENTARY W/INVER
MFG: MOT 6 DEVICES TEST DATE 06-17-86
REF: JPL LOG 1377 DATE CODE FR 8705

DOSE, rads(Si) Co\textsuperscript{60} Gammas
20 rads/sec Dose Rate

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IDSP</th>
<th>ON/OFF</th>
<th>CODE</th>
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<tr>
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<tr>
<td>C</td>
<td>(6)</td>
<td>IDSP(10)-OFF</td>
<td>(A)</td>
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</table>
DEVICE TYPE: MC14007 D COMPLIMENTARY W/INVER
MFG: MOT 6 DEVICES TEST DATE 06-17-88
REF: JPL LOG 1377 DATE CODE FR 8705

PARAMETERS

CURVE A: [7] VTN(6)-ON (V1)
CURVE B: [8] VTN(3)-OFF (V1)
CURVE C: [9] VTP(10)-ON (V1)
DEVICE TYPE: MC14007 D COMPLIMENTARY W/INVER
MFG: MOT 6 DEVICES TEST DATE 08-17-88
REF: JPL LOG 1377 DATE CODE FR 8705

PARAMETERS
CURVE A: (101) VTP(6)-ON (VI)
CURVE B: (111) VTP(3)-OFF (VI)
CURVE C: (121) VTP(10)-OFF(VI)
PARAMETERS

Curve A: IDSN(6)--ON (A)
Curve B: IDSN(3)--OFF (A)
Curve C: IDSN(10)--ON (A)
Device Type: MC14037 CMOS INVERTER
MFG: MCT 5 Devices Test Date 10-10-88
Ref: JPL LOG 1392 Date Code FF 87361

Dose, rads(S) Co\textsuperscript{60} Gammas
0.0156 rads/sec Dose Rate

Parameters

Parameter Mean Value

Pre-Rad

Dose rates (A)

Curve A: (4) IDSP(6)-ON (A)
Curve B: (5) IDSP(3)-OFF (A)
Curve C: (6) IDSP(10)-OFF (A)
PARAMETERS

CURVE A: (7) VTN(6)-ON (V)
CURVE B: (8) VTN(3)-OFF (V)
CURVE C: (9) VTP(10)-ON (V)
DEVICE TYPE: MC14007 CMOS INVERTER
MFG: MCT 5 DEVICES TEST DATE 10-10-88
REF: JPL L08 1392 DATE CODE FF 87361

PARAMETERS

CURVE A: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF(V)

DOSE, rads(Si) Co\textsuperscript{60} Gammas
0.0156 rads/sec Dose Rate

PRE-RAD

PARAMETER MEAN VALUE

1.5  2.  2.5  3.  3.5  4.  4.5  5.

-1.47 -1.43 -1.39 -1.35 -1.30 -1.26 -1.22 -1.17 -1.13
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
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</thead>
<tbody>
<tr>
<td>DOSE, rad S</td>
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<tr>
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<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E6 3.0E6 6.0E6 2.4E1</td>
</tr>
<tr>
<td>STD. DEV.</td>
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<table>
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</tr>
<tr>
<td></td>
<td>7.2E1 2.4E2 7.2E2 2.4E3</td>
</tr>
<tr>
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<td>.1086 .1122 .1196 .1161</td>
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TABLE OF NORMAL STANDARD DEVIATIONS

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<td>7.2E1 2.4E2 7.2E2 2.4E3</td>
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TABLE OF NORMAL STANDARD DEVIATIONS

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<td>1.0E6</td>
<td>1.0E0</td>
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<td>1.0E6</td>
<td>2.0E6</td>
<td>3.0E0</td>
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<td>6.0E5</td>
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<td>6.0E0</td>
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<td>1.0E6</td>
<td>3.0E0</td>
<td>2.4E1</td>
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TABLE OF NORMAL STANDARD DEVIATIONS

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<th>TIME, hours</th>
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STD. DEV.:

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<th>STD. DEV.</th>
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<td>1.0E7</td>
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INITIAL MEAN VALUE +GAIN(DB) = +1.24X10²
DEVICE TYPE: OP-27 OP AMP
MFG: SUB 5 DEVICES TEST DATE 05-15-86
REF: JPL LOG 1162 DATE CODE 8503

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>Dose/Hours</th>
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<th>STD. Dev.</th>
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<tbody>
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<td>7.2E1</td>
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INITIAL MEAN VALUE -GAIN(DB) = +1.23X10^2
DEVICE TYPE: OP-27 OP AMP
MFG: LTC 5 DEVICES TEST DATE 05-15-86
REF: JPL LOG 1142 DATE CODE 8576

(2) ION IN NA VS DOSE

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(Si)</th>
<th>TIME, hours</th>
</tr>
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<tr>
<td>3.064</td>
<td>7.564</td>
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<td>2.463</td>
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STD. DEV.    | 19.49 21.19 104.9 72.62 58.70 40.00 15.17 6.933 3.742 6.368

* MEASUREMENT PROBLEM
DEVIGE TYPE: OP-27 OP AMP
MFG: LTC 5 DEVICES TEST DATE 05-15-66
REF: JPL LOG 1142 DATE CODE E578

TABLE OF NORMAL STANDARD DEVIATIONS

| DOSE/HOURS | 3.0E4 7.5E4 1.5E5 3.0E5 1.0E6 4.6E1 7.2E1 2.4E2 7.2E2 2.4E3 | 2.062 4.910 1.559 XXXXX 13.16 12.91 10.55 5.424 4.544 10.44 |
| STANDARD DEVIATION | 2.062 4.910 1.559 XXXXX 13.16 12.91 10.55 5.424 4.544 10.44 |

INITIAL MEAN VALUE +GAIN(DB) = +1.3X10^2
DEVICE TYPE: OP-27 OP AMP
MFG: LTC 5 DEVICES
TEST DATE 05-15-86
REF: JPL LOG 2142
DATE CODE 8578

TABLE OF NORMAL STANDARD DEVIATIONS

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<th>I0 (mA)</th>
<th>DOSE (rad(Si))</th>
<th>TIME, hours</th>
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INITIAL MEAN VALUE -GAIN(DB) = +1.49X10^2

5-181
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
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<tr>
<th>DOSE/HOURS</th>
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</table>

(1) VOS IN MV VS DOSE

DOSE, rads(Si) Ca^{60} Gammas

TIME, hours
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(Si)</th>
<th>TIME, hours</th>
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<tbody>
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<tr>
<td>7.7E3</td>
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Table of Normal Standard Deviations

<table>
<thead>
<tr>
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<th>Time (hours)</th>
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<tbody>
<tr>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E0 3.0E0 6.0E0 2.4E1</td>
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<tr>
<td>Dose/Hours</td>
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<td>Std. Dev.</td>
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</table>
DEVICE TYPE: OP-27 OP AMP
MFG: MPS 4 DEVICES TEST DATE 06-11-86
REF: JPL LOG 1147 DATE CODE 6350

D O S E , r a d s ( S ; ) C a 6 0 G a m m a s
E O R T I M E , h o u r s

(4) +G A I N (1K LO A D : 1 0 M A , + 1 0 V ) I N D B V S D O S E

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<tr>
<th>DOSE/HOURS</th>
<th>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E7 3.0E7 6.0E7 2.0E8</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>7.2E1 2.4E2 7.2E2</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>3.900 3.360 2.978</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE +GAIN(DB) = +1.26X10^9
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>Dose (rads(Si))</th>
<th>Time, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
<td>1.5E5</td>
</tr>
<tr>
<td>3.0E5</td>
<td>6.0E5</td>
<td>1.0E6</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.0E0</td>
<td>2.0E0</td>
</tr>
<tr>
<td>3.0E0</td>
<td>6.0E0</td>
<td>2.4E1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STD. DEV.</th>
<th>.4139</th>
<th>.9143</th>
</tr>
</thead>
<tbody>
<tr>
<td>.0000</td>
<td>2.535</td>
<td>1.704</td>
</tr>
<tr>
<td>2.535</td>
<td>1.441</td>
<td>1.119</td>
</tr>
<tr>
<td>1.704</td>
<td>.9329</td>
<td>1.119</td>
</tr>
<tr>
<td>1.441</td>
<td>1.119</td>
<td>1.119</td>
</tr>
<tr>
<td>1.119</td>
<td>1.119</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>Dose (rads(Si))</th>
<th>Time, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2E1</td>
<td>2.4E2</td>
<td>7.2E2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STD. DEV.</th>
<th>1.500</th>
<th>1.500</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.500</td>
<td>1.249</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE -GAIN (DB) = +1.26X10^2
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(S)</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
<td>1.5E5</td>
</tr>
<tr>
<td>3.0E4</td>
<td>6.0E5</td>
<td>1.0E6</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.9E0</td>
<td>3.0E0</td>
</tr>
<tr>
<td>6.0E0</td>
<td>2.4E1</td>
<td></td>
</tr>
</tbody>
</table>

| STD. DEV. | .0130        | .0434       |
|           | .1567        | .1665       |
|           | .2199        | .1162       |
|           | .0980        | .0693       |
|           | .0583        |             |

| DOSE/HOURS | 7.2E1        | 2.4E2       |
|           | 7.2E2        |             |

| STD. DEV. | .0469        | .0277       |
|           | .0225        |             |
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(Si) Co\textsuperscript{60} Gammas</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9E4</td>
<td>7.6E4</td>
<td>6.0E5</td>
</tr>
<tr>
<td>3.0E5</td>
<td>6.0E5</td>
<td>6.0E5</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.0E6</td>
<td>1.0E6</td>
</tr>
<tr>
<td>3.0E6</td>
<td>6.0E6</td>
<td>6.0E6</td>
</tr>
<tr>
<td>2.4E1</td>
<td>2.4E2</td>
<td>2.4E2</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>62.67</td>
<td>193.5</td>
</tr>
<tr>
<td>296.4</td>
<td>257.9</td>
<td>147.2</td>
</tr>
<tr>
<td>226.0</td>
<td>226.0</td>
<td>221.6</td>
</tr>
<tr>
<td>254.1</td>
<td>266.4</td>
<td>313.5</td>
</tr>
<tr>
<td>Dose/Hours</td>
<td>7.2E1</td>
<td>2.4E2</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>321.7</td>
<td>268.3</td>
</tr>
<tr>
<td>250.0</td>
<td>266.4</td>
<td>313.5</td>
</tr>
</tbody>
</table>

5-188
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E6 3.0E6 6.0E6 2.4E1</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>52.92  166.7  581.6  491.6  493.4  433.0  491.6  414.9  360.5  311.5  227.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>7.2E1 2.4E2 7.2E2</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>166.1  128.1  97.92</td>
</tr>
</tbody>
</table>
DEVICE TYPE: OP-27 OP AMP
MFG: DAZY 5 DEVICES TEST DATE 06-11-86
REF: JPL LOG 1168 DATE CODE 8230

(4) GAIN (1K LOAD-10mA, +10V) IN DB VS DOSE

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(US)</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
<td>1.5E3</td>
</tr>
<tr>
<td>6.0E3</td>
<td>3.0E4</td>
<td>1.0E6</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.0E9</td>
<td>3.0E6</td>
</tr>
<tr>
<td>6.0E2</td>
<td>2.0E3</td>
<td>2.0E6</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.0E9</td>
<td>3.0E6</td>
</tr>
</tbody>
</table>

STD. DEV. 1.131 1.264 1.603 3.366 2.737 2.771 2.936 2.909 2.610 .6195 1.603

DOSE/HOURS 7.2E2 2.4E2 7.2E2

STD. DEV. 1.264 .6927 1.575

INITIAL MEAN VALUE +GAIN(DB) = +1.24X10^12

5-190
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>Dose (rads)</th>
<th>Time (hours)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>1.294</td>
<td>1.218</td>
</tr>
<tr>
<td>7.5E4</td>
<td>0.5166</td>
<td>0.6353</td>
</tr>
<tr>
<td>1.5E5</td>
<td>0.7727</td>
<td>0.7727</td>
</tr>
<tr>
<td>3.0E5</td>
<td>0.9690</td>
<td>1.173</td>
</tr>
<tr>
<td>6.0E5</td>
<td>1.065</td>
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<tr>
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<td>1.7727</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.905</td>
<td></td>
</tr>
<tr>
<td>3.0E6</td>
<td>2.481</td>
<td></td>
</tr>
<tr>
<td>6.0E6</td>
<td>2.481</td>
<td></td>
</tr>
<tr>
<td>1.0E7</td>
<td>2.481</td>
<td></td>
</tr>
</tbody>
</table>

Initial mean value: \(-\text{gain} (\text{DB}) = +1.24 \times 10^3\)
DEVICE TYPE: OPA111 FET-INPUT OP-AMP
MFG: ROB 5 DEVICES TEST DATE 10-17-85
REF: JPL LOG 1190 DATE CODE 6449

DOSE, rads(Si) 2.5 MeV electrons

(1) VOS IN MV VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.000 1.565 3.905 6.955 1.265 3.966 1.267</td>
<td>0.050 0.0745 0.2361 0.4535 0.6649 1.679 3.080</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOS(MV) = +3.57X10^-2

5-192
DEVICE TYPE: OPA111 FET-INPUT OP-AMP
REF: JPL LOG 1116
DATE CODE 8449

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.0E3 1.5E3 3.0E3 6.0E3 1.0E4 3.0E4 1.0E6</td>
<td>2.0E3 1.5E3 3.0E3 6.0E3 1.0E4 3.0E4 1.0E6</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>1.163 2.466 0.6662 1.6390 1.678 0.9340 2.971</td>
<td>1.163 2.466 0.6662 1.6390 1.678 0.9340 2.971</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE I0S(PA) = +1.60X10^2

5-193
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>Dose</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5 MeV electrons</td>
<td>0.060 1.5E3 3.0E3 6.0E3 1.0E6 3.0E6 1.0E7</td>
<td>4523 2.014 3.965 6.449 10.07 21.14 36.64</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE I2(PA) = +1.10 x 10⁻⁶
DEVICE TYPE: OPA111 FET-INPUT OP-AMP

5 DEVICES TEST DATE 10-09-85

PRE-RAD

MEAN VOS(MV)

DOSE, rad(s) Co\textsuperscript{60} Gammas

(1) VOS IN MV: VS DOSE

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE (rad(s))</th>
<th>STD. DLV.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.000</td>
<td>1.5E5</td>
</tr>
<tr>
<td></td>
<td>0.0580</td>
<td>.1696</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOS(MV) = -6.61 x 10\textsuperscript{-4}

5-195
DEVICE TYPE: OPA111 FET-INPUT OP-AMP

MFG: BUR 5 DEVICES TEST DATE 10-09-65

REF: JPL L06 1199 DATE CODE 8449

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(SI)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.0E0 1.5E3 3.0E3 6.0E3 1.9E6 3.0E6 1.0E7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.348 0.256 0.591 0.816 0.166 0.101 0.172</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE I0S(PA) = 6.86X10^-1

5-196
DEViCE TYPE: UPA111 FET-INPUT OP-AMP
NEG: BOC 3 DEVICES TEST DATE 10-09-65
REF: JPL LOG 1199 DATE CODE 6449

Dose, rads(Si) Co\textsuperscript{60} Gammas

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>6.8E0 1.8E3 3.9E3 6.9E3 1.0E6 3.0E6 1.0E7</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>86.27 2.143 5.341 13.35 12.69 66.61 74.61</td>
</tr>
</tbody>
</table>

Initial Mean Value I(B(An)) = +1.15x10\textsuperscript{-3}
APPENDIX A

VENDOR IDENTIFICATION CODE LIST
<table>
<thead>
<tr>
<th>Code</th>
<th>Company Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD</td>
<td>Advanced Microdevices Corporation</td>
</tr>
<tr>
<td>BUB</td>
<td>Burr-Brown</td>
</tr>
<tr>
<td>FSC</td>
<td>Fairchild Semiconductor</td>
</tr>
<tr>
<td>LTC</td>
<td>Linear Technology, Inc.</td>
</tr>
<tr>
<td>MOT</td>
<td>Motorola, Inc., Semiconductor Products Division</td>
</tr>
<tr>
<td>MPS</td>
<td>Micro Power Systems, Inc.</td>
</tr>
<tr>
<td>NSC</td>
<td>National Semiconductor Corporation</td>
</tr>
<tr>
<td>PPC</td>
<td>PPC Products, Inc.</td>
</tr>
<tr>
<td>RAY</td>
<td>Ratheon Co., Semiconductor Division</td>
</tr>
<tr>
<td>RCA</td>
<td>RCA Corporation, Solid State Division</td>
</tr>
<tr>
<td>SGS</td>
<td>SGS Semiconductors</td>
</tr>
<tr>
<td>SSS</td>
<td>Solid State Scientific Corp.</td>
</tr>
<tr>
<td>TIX</td>
<td>Texas Instruments, Inc.</td>
</tr>
</tbody>
</table>
APPENDIX B

ELECTRICAL PARAMETER SYMBOLS AND ABBREVIATIONS
ELECTRICAL PARAMETER SYMBOLS AND ABBREVIATIONS

DNL  Diff. Non-Linearity
HFE  DC Current Gain
+ Gain    Open Loop Gain
- Gain    Open Loop Gain
IB      Bias Current
ICCH    Supply Current with Input High, Output Open
ICCL    Supply Current with Input Low, Output Open
ICCZ    Supply Current with Input Low, Outputs at VCC and Tri-Stated
IDSN    Drain Source Current, N-channel
IDSP    Drain Source Current, P-channel
IFSS    Full-Scale Output Symmetry
IIH     Input Current High
IIL     Input Current Low
IOH     High-Level Output Current
IOL     Low-Level Output Current
IOS     Input Offset Current
IOZH    Tri-State Output Leakage Current, Outputs High
IOZL    Tri-State Output Leakage Current, Outputs Low
IQH     Quiescent Current High
IQL     Quiescent Current Low
IREF    Ref. Input Bias Current
IZS     Zero Scale Output Current
NONLIN  Nonlinearity
PO      Relative Output Power
PSS     Power Supply Sensitivity
TF      Fall Time
TPHL    Propagation Delay Time High- to Low-Level Output
TPLH    Propagation Delay Time Low- to High-Level Output
TR      Rise Time
VF      Forward Voltage
VOH     High-Level Output Voltage
VOL     Low-Level Output Voltage
VOS     Offset Voltage
VTN     Threshold Voltage n-channel Transistor
VTP     Threshold Voltage p-channel Transistor