Total-Dose Radiation Effects Data for Semiconductor Devices
1989 Supplement

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NASA
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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Washington, D.C. 20546

**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).

**Key Words (Selected by Author(s)):**
Astronautics; Nuclear Science and Technology (General); Space Sciences (General); Flight Projects (General); Ionizing Radiation; Tolerance; Bipolar Transistors; Integrated Circuits

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This notice is an update regarding the method of accessing the JPL/NASA electronic data bank (called RADATA), that is accessible on either of two JPL 11/780 VAX computers. For those not familiar with RADATA, a brief description will be given:

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.

To access RADATA, use full duplex (the system uses auto baud rate detection for speeds up to 9600 baud), 8 bit format, 1 stop bit and no parity. After you have set protocol, use one of the following methods to access RADATA:

ACCESS AT JPL:

1. Direct dial X4-4360 or access ILAN and connect to the "VLSI" or the "DSFVAX".
2. Enter RADATA to the USERNAME: prompt and press RETURN/ENTER.

ACCESS USING OFF-LAB TELEPHONE DIAL-UP:

1. Dial (818)354-4360 (VLSI VAX).
2. After the CONNECT prompt, press the RETURN/ENTER key twice, then input RADATA to the USERNAME prompt and press RETURN/ENTER again.

(Alternate OFF-LAB back-up access):
If RADATA cannot be accessed on the VLSI VAX [dialing (818)354-4360)], use the following back-up method:

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.

ACCESS USING DEChnet(SPAN):
If your facility has a VAX computer tied to DEChnet you may access RADATA as follows:

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

ACCESS USING TELNET:
If your facility is tied into MILNET or ARPANET, you may access RADATA as follows:

1. Enter TELNET VLSI.JPL.NASA.GOV or TELNET DSFVAX.JPL.NASA.GOV after the prompt sign.
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.

Footnote:

RADATA is sponsored by the NASA Office of Safety, Reliability, Maintainability and Quality Assurance and is carried out by the JPL Electronic Parts Reliability Section.
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In order to maximize the effectiveness and convenience of using the RADATA Electronic Ground Test Radiation Data Bank, we are requesting you fill out and return this questionnaire:

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
Total-Dose Radiation Effects
Data for Semiconductor Devices
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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


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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.
## INDEX OF DEVICE TYPES

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*See Appendix A
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/cm²/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)
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
\[
\Delta(1/h_{FE}) = 1/h_{FE} - 1/h_{FE_0},
\]
where \( h_{FE} \) is the value at the specified radiation level, and \( h_{FE_0} \) 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:
\[
h_{FE}(\text{final}) = \frac{1}{\Delta(1/h_{FE}) + \frac{1}{h_{FE_0}(\text{initial})}}
\]
\[
h_{FE}(\text{final}) = \frac{1}{0.008 + \frac{1}{100}} = 55.6
\]

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 $h_{FE}$.

Figure 5-1. Graph Format Description
| $\Delta h_{FE}^\omega$ | 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 |
|---------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0.0005  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.0025  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.0050  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.0100  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.0200  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.0300  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.0400  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.0600  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.0800  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.1000  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.1500  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.2000  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.3000  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |
| 0.4000  | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 49.8 | 55.8 | 62.9 | 70.5 | 78.2 | 87.0 | 96.8 | 106 | 118 | 132 | 144 | 159 | 175 | 194 | 215 | 238 | 264 | 293 | 323 |

Table 5-1. Determination of Final $h_{FE}^\omega$, Given Initial $h_{FE0}$ and Postirradiation $\Delta(1/h_{FE})$.  

5-3
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: FSC  4 DEVICES  TEST DATE 02-20-66
REF: JPL LOG 1246  DATE CODE 8352

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REF: JPL LOG 1225 DATE CODE 8530

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<td>10^4 1.5E4 3.0E4 6.0E4 1.0E6</td>
</tr>
<tr>
<td>A</td>
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<td>20.0</td>
<td>0.0066 0.0085 0.0108 0.0127 0.0157</td>
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<td>0.0061 0.0087 0.0105 0.0132 0.0171</td>
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<td>1.000</td>
<td>100</td>
<td>0.0023 0.0031 0.0039 0.0036 0.0060</td>
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<tr>
<td>D</td>
<td>1.000</td>
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<td>0.0019 0.0025 0.0036 0.0040 0.0049</td>
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<tr>
<td>E</td>
<td>20.00</td>
<td>20.0</td>
<td>0.0014 0.0004 0.0010 0.0020 0.0005</td>
</tr>
<tr>
<td>F</td>
<td>20.00</td>
<td>500</td>
<td>0.0007 0.0010 0.0010 0.0014 0.0013</td>
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</table>
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MOT 5 DEVICES TEST DATE 2-04-86
REF: JPL LOG 1226 DATE CODE 8530

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

<table>
<thead>
<tr>
<th>CURVE</th>
<th>( I_c )</th>
<th>( V_{ce} )</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[mA]</td>
<td>[V]</td>
<td>7.5E5</td>
</tr>
<tr>
<td>A</td>
<td>1.000</td>
<td>0.0005</td>
<td>0.0005</td>
</tr>
<tr>
<td>B</td>
<td>1.000</td>
<td>0.0014</td>
<td>0.0014</td>
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<tr>
<td>C</td>
<td>1.000</td>
<td>0.0013</td>
<td>0.0013</td>
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<tr>
<td>D</td>
<td>20.00</td>
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<td>0.0006</td>
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<tr>
<td>E</td>
<td>20.00</td>
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</tr>
<tr>
<td>F</td>
<td>20.00</td>
<td>0.0008</td>
<td>0.0008</td>
</tr>
</tbody>
</table>
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MOT 5 DEVICES TEST DATE 2-04-66
REF: JPL LOG 1227 DATE CODE 8530

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

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Ic (mA)</th>
<th>Vce (V)</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.5E4 1.5E5 3.0E5 6.0E5 1.0E6</td>
</tr>
<tr>
<td>A</td>
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<td>20.0</td>
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<tr>
<td>B</td>
<td>1.000</td>
<td>.500</td>
<td>.0029 .0026 .0023 .0022 .0039</td>
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<tr>
<td>C</td>
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<td>.500</td>
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<tr>
<td>D</td>
<td>1.000</td>
<td>20.0</td>
<td>.0011 .0007 .0008 .0047 .0010</td>
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<tr>
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<td>20.0</td>
<td>.0003 .0002 .0002 .0003 .0003</td>
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<td>.0003 .0007 .0002 .0003 .0003</td>
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</table>

TABLE OF NORMAL STANDARD DEVIATIONS

5-7
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MJT 5 DEVICES TEST DATE 2-04-86
REF: JPL LOG 1228 DATE CODE 8330

DOSE, rads(Si) 2.5 MeV electrons
Δ(1/βP) VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Ic (mA)</th>
<th>Vbe (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>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.000</td>
<td>20.0</td>
<td>.0026</td>
<td>.0305</td>
<td>.0158</td>
<td>.0102</td>
<td>.0126</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1.000</td>
<td>50.0</td>
<td>.0026</td>
<td>.0302</td>
<td>.0153</td>
<td>.0108</td>
<td>.0104</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1.000</td>
<td>50.0</td>
<td>.0011</td>
<td>.0152</td>
<td>.0054</td>
<td>.0035</td>
<td>.0031</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1.000</td>
<td>20.0</td>
<td>.0009</td>
<td>.0091</td>
<td>.0075</td>
<td>.0045</td>
<td>.0032</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>20.00</td>
<td>20.0</td>
<td>.0003</td>
<td>.0020</td>
<td>.0012</td>
<td>.0010</td>
<td>.0011</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>20.00</td>
<td>50.0</td>
<td>.0003</td>
<td>.0023</td>
<td>.0012</td>
<td>.0008</td>
<td>.0011</td>
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</table>
**DEVICE TYPE:** 2N2222A NPN TRANSISTOR

**MFG:** MOT

**5 DEVICES** **TEST DATE** 2-04-86

**REF:** JPL LOG 1229 **DATE CODE** 8530

---

**DOSE, rods(S:) 2.5 MeV electrons**

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

---

**TABLE OF NORMAL STANDARD DEVIATIONS**

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Ic (mA)</th>
<th>Vcc (v)</th>
<th>DOSE, rods(S:)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.5E4 1.5E5 3.0E5 6.0E5 1.0E6</td>
</tr>
<tr>
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<td>.1000</td>
<td>20.0</td>
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<tr>
<td>B</td>
<td>.1000</td>
<td>.500</td>
<td>.0014 .0022 .0029 .0056 .0029</td>
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<tr>
<td>C</td>
<td>1.000</td>
<td>.500</td>
<td>.0006 .0007 .0008 .0027 .0009</td>
</tr>
<tr>
<td>D</td>
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<tr>
<td>F</td>
<td>20.00</td>
<td>.500</td>
<td>.0002 .0002 .0003 .0003 .0003</td>
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</tbody>
</table>
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MOT 5 DEVICES TEST DATE 02-04-86
REF: JPL LOG 1330 DATE CODE 8530

DOSE, rads(Si) 2.5 MeV electrons
Δ(1/hke) VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Ic</th>
<th>Vce</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>V</td>
<td>7.5E-4 1.5E-5 3.0E-5 6.0E-5 1.0E-6</td>
</tr>
<tr>
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<td>.000</td>
<td>20.0</td>
<td>.0012 .0017 .0031 .0045 .0043</td>
</tr>
<tr>
<td>B</td>
<td>1.000</td>
<td>.500</td>
<td>.0013 .0020 .0017 .0062 .0041</td>
</tr>
<tr>
<td>C</td>
<td>1.000</td>
<td>.500</td>
<td>.0006 .0004 .0017 .0013 .0019</td>
</tr>
<tr>
<td>D</td>
<td>20.00</td>
<td>20.0</td>
<td>.0006 .0009 .0009 .0004 .0016</td>
</tr>
<tr>
<td>E</td>
<td>20.00</td>
<td>.500</td>
<td>.0002 .0002 .0008 .0002 .0003</td>
</tr>
<tr>
<td>F</td>
<td>.0000</td>
<td>.000</td>
<td>.0001 .0003 .0007 .0003 .0004</td>
</tr>
</tbody>
</table>
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MOT 5 DEVICES TEST DATE 02-05-86
REF: JPL LOG 1231 DATE CODE 8530

DOSE, rads(Si) 2.5 MeV electrons
Δ(1/hFE) VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IC (mA)</th>
<th>VCE (v)</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.1000</td>
<td>20.0</td>
<td>7.5E4 1.5E3 3.2E3 6.0E3 1.0E6</td>
</tr>
<tr>
<td>B</td>
<td>.1000</td>
<td>.500</td>
<td>.0049 .0068 .0072 .0062 .0065</td>
</tr>
<tr>
<td>C</td>
<td>1.000</td>
<td>.500</td>
<td>.0056 .0091 .0036 .0086 .0078</td>
</tr>
<tr>
<td>D</td>
<td>1.000</td>
<td>20.0</td>
<td>.0016 .0039 .0044 .0020 .0024</td>
</tr>
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<td>20.0</td>
<td>.003 .0002 .0048 .0008 .0003</td>
</tr>
<tr>
<td>F</td>
<td>20.00</td>
<td>.500</td>
<td>.0003 .0005 .0006 .0011 .0006</td>
</tr>
</tbody>
</table>
DEVICE TYPE: 2N3949 NPN POWER TRANSISTOR
MFG: APC 3 DEVICES TEST DATE 12-19-85
REF: JPL LOG 1211 DATE CODE 8510

**TABLE OF NORMAL STANDARD DEVIATIONS**

<table>
<thead>
<tr>
<th>CURVE</th>
<th>I&lt;sub&gt;e&lt;/sub&gt; (mA)</th>
<th>V&lt;sub&gt;ce&lt;/sub&gt; (V)</th>
<th>DOSE, rads(Si) Co&lt;sup&gt;60&lt;/sup&gt; Gammas</th>
<th>Δ(1/h&lt;sub&gt;fe&lt;/sub&gt;) VS DOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.000</td>
<td>5.000</td>
<td>3.0E+4 7.5E+4 1.5E5 3.0E5 6.0E5</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>10.000</td>
<td>5.000</td>
<td>0.0402 0.2381 0.6168 1.062 1.034</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>100.0</td>
<td>5.000</td>
<td>0.0110 0.0429 0.044 1.250 6.457</td>
<td></td>
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<td>1000.0</td>
<td>5.000</td>
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5-12
DEVICES TYPE: 2N3749 NPN
MFG: PPC 3 DEVICES TEST DATE 01-08-86
REF: JPL LOG 1212 DATE CODE 8515

![Graph showing the relationship between dose and 
\(\Delta(1/h_{Fe})\) vs dose.]

<table>
<thead>
<tr>
<th>CURVE</th>
<th>(I_c) (mA)</th>
<th>(V_{ce}) (V)</th>
<th>DOSE, rads(Si)</th>
<th>(\Delta(1/h_{Fe}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100.0</td>
<td>5.00</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5</td>
<td>0.0016 0.0038 0.0040 0.0045 0.0045</td>
</tr>
<tr>
<td>B</td>
<td>100.0</td>
<td>5.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1000.0</td>
<td>5.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1000.0</td>
<td>5.00</td>
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DEVICE TYPE: MJ16012 NPN POWER TRANSISTOR
MFG: HOT 5 DEVICES TEST DATE 12-17-85
REF: JPL LOG 1220 DATE CODE NONE

Table of normal standard deviations:

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IC (mA)</th>
<th>VCE (V)</th>
<th>DOSE, rads(Si) 2.5 MeV electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10^3 10^4 10^5 10^6 10^7</td>
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<tr>
<td>A</td>
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<td>50.0</td>
<td>0.0072 0.0127 0.0164 0.0219 0.0373 0.0319 0.0312</td>
</tr>
<tr>
<td>B</td>
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<td>150.0</td>
<td>0.0063 0.0114 0.0169 0.0226 0.0373 0.0285 0.0247</td>
</tr>
<tr>
<td>C</td>
<td>1000.0</td>
<td>50.0</td>
<td>0.0025 0.0050 0.0077 0.0103 0.0168 0.0119 0.0135</td>
</tr>
<tr>
<td>D</td>
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<td>500.0</td>
<td>0.0029 0.0062 0.0071 0.0093 0.0102 0.0121 0.0174</td>
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<tr>
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</table>

5-14
DEVICE TYPE: MJ16012 NPN POWER TRANSISTOR
MFG: M07 5 DEVICES TEST DATE 12-12-85
REF: JPL LOG 1221 DATE CODE NONE

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

\[ \Delta(1/h_{fe}) \text{ vs DOSE} \]

<table>
<thead>
<tr>
<th>CURVE</th>
<th>( I_C )</th>
<th>( V_{ce} )</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(mA)</td>
<td>(V)</td>
<td>( 3.0 \times 10^4 )</td>
</tr>
<tr>
<td>A</td>
<td>100.0</td>
<td>50.0</td>
<td>0.0043</td>
</tr>
<tr>
<td>B</td>
<td>100.0</td>
<td>500.0</td>
<td>0.0046</td>
</tr>
<tr>
<td>C</td>
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<td>0.0016</td>
</tr>
<tr>
<td>D</td>
<td>1000.0</td>
<td>500.0</td>
<td>0.0025</td>
</tr>
<tr>
<td>E</td>
<td>10000.0</td>
<td>50.0</td>
<td>0.0034</td>
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</tbody>
</table>

5-15
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>
<thead>
<tr>
<th>Po @ Pre</th>
<th>IF(mA)</th>
<th>20</th>
<th>20</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>
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<tr>
<td>40</td>
<td>971.1</td>
<td>692.5</td>
<td>496.2</td>
<td>195.0</td>
<td>320.0</td>
<td>580.0</td>
</tr>
<tr>
<td>60</td>
<td>1558.0</td>
<td>1163.0</td>
<td>868.8</td>
<td>368.8</td>
<td>568.8</td>
<td>977.5</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>
</tr>
<tr>
<td>100</td>
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<td>2623.0</td>
<td>1620.0</td>
<td>772.5</td>
<td>1097.0</td>
<td>1741.0</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>
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<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

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

- $P_0$ @ IF = 20mA
- $P_0$ @ IF = 40mA
- $P_0$ @ IF = 60mA
- $P_0$ @ IF = 80mA
- $P_0$ @ IF = 100mA

4/27/87
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>4.070</th>
<th>1.927</th>
<th>1.426</th>
<th>0.845</th>
<th>0.920</th>
<th>0.883 mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mA (7mW/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>40 mA (17mW/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>60 mA (20mW/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>80 mA (27mW/cm²)</td>
<td>18.850</td>
<td>12.490</td>
<td>10.810</td>
<td>7.173</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 7 mW/cm²</td>
<td>VCE = 5V, IF = 20 mA from reference source</td>
</tr>
<tr>
<td>4</td>
<td>I-LITE2</td>
<td>LIGHT CURRENT 17 mW/cm²</td>
<td>VCE = 5V, IF = 40 mA from reference source</td>
</tr>
<tr>
<td>5</td>
<td>I-LITE3</td>
<td>LIGHT CURRENT 20 mW/cm²</td>
<td>VCE = 5V, IF = 60 mA from reference source</td>
</tr>
<tr>
<td>6</td>
<td>I-LITE4</td>
<td>LIGHT CURRENT 27 mW/cm²</td>
<td>VCE = 5V, IF = 80 mA from reference source</td>
</tr>
<tr>
<td>7</td>
<td>I-LITE5</td>
<td>LIGHT CURRENT 33 mW/cm²</td>
<td>VCE = 5V, 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.

Figure 5-2. Typical Integrated Circuit Graph Format Example

2The 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: 54A6374  OCTAL D-TYPE 11F
MFG: FSC  3 DEVICES  TEST DATE 2-11-87
REF: JPL LOG 1296  DATE CODE 8633

PARAMETER MEAN VALUE

DOSE, rads(Si) Co⁶⁰ Gammas  TIME, hours

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURVE A:</td>
<td>(3) VOL1-A (V)</td>
<td>(IOUT = 20 MA)</td>
</tr>
<tr>
<td>CURVE B:</td>
<td>(6) VOL1-B (V)</td>
<td>*</td>
</tr>
<tr>
<td>CURVE C:</td>
<td>(7) VOL2-A (V)</td>
<td>(IOUT = 24 MA)</td>
</tr>
<tr>
<td>CURVE D:</td>
<td>(8) VOL2-B (V)</td>
<td>*</td>
</tr>
</tbody>
</table>
DEVI CE 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) IIH-B (A) * *
CURVE C: (11) IIL-A (A) (VIN = GND)
CURVE D: (12) IIL-B (A) * *
DEVELOPMENT TYPE: 54AC374 OCTAL D-TYPE FF
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>10Z1H1-A (A)</td>
<td>(VIN = 3.66 V)</td>
</tr>
<tr>
<td>B</td>
<td>10Z1H1-B (A)</td>
<td>*</td>
</tr>
<tr>
<td>C</td>
<td>10Z1H2-A (A)</td>
<td>(VIN = 1.64 V)</td>
</tr>
<tr>
<td>D</td>
<td>10Z1H2-B (A)</td>
<td>*</td>
</tr>
</tbody>
</table>
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: 10ZL1-A (A) [VIN = 3.66 V]
CURVE B: 10ZL1-B (A) *
CURVE C: 10ZL2-A (A) [VIN = 1.64 V]
CURVE D: 10ZL2-B (A) *

DOS, rads(Si) Co²⁰ Gammas TIME, hours

PARAMETER MEAN VALUE

PRE-RAD $10^{-2}$ $10^{-3}$ $10^{-4}$ $10^{-5}$ $10^{-6}$ $10^{-7}$ $10^{-8}$ $10^{-9}$
COR $3.4.5.6.7.8.9.10.11.12.13.14.15.16.17.18.19.20.21.22.23.24.25.26.27.28$
DEVICE TYPE: 54AG374 OCTAL D-TYPE F/F
MFG: FSC  3 DEVICES  TEST DATE 2-11-87
REF: JPL LOG 1296  DATE CODE 8633

PARAMETERS

CURVE A: (22) IGGH-B (A)
CURVE B: (24) ICCL-E (A)
CURVE C: (26) ICCZ-B (A)
DEVICE TYPE: 54AC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1300 DATE CODE 6627

PARAMETERS
CURVE A: (1) VOH1-A (V) (IOUT = -20 UA)
CURVE B: (2) VOH1-B (V) • • •
DEVICE TYPE: 54AG87  OCTAL D-TYPE F/F
MFG: NSC    3 DEVICES TEST DATE 3-24-67
REF: JPL LOG 1300 DATE CODE 8627

PARAMETERS
CURVE A:  (3) V0H2-A (V)  
CURVE B:  (4) V0H2-B (V)  

CONDITIONS
(10UT = -5.2 MA)
DEVICE TYPE: 54AC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-67
REF: JPL LOG 1300 DATE CODE 6627

PARAMETERS

CURVE A: (3) VOL1-A (V) [\text{IOUT} = 20 \text{ UA}]
CURVE B: (6) VOL1-B (V) * *
CURVE C: (7) VOL2-A (V) [\text{IOUT} = 5.2 \text{ mA}]
CURVE D: (4) VOL2-B (V) * *
### Parameters and Conditions

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(9) I1+I2</td>
<td>(A) [VIN = VCC]</td>
</tr>
<tr>
<td>B</td>
<td>(101) I1+I2</td>
<td>(A) *</td>
</tr>
<tr>
<td>C</td>
<td>(111) I1+I2</td>
<td>(A) [VIN = GND]</td>
</tr>
<tr>
<td>D</td>
<td>(122) I1+I2</td>
<td>(A) *</td>
</tr>
</tbody>
</table>
DEVICE TYPE: 54AC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1300 DATE CODE 8627

PARAMETERS CONDITIONS

CURVE A: 107H3-A (A) (VIN = 4.2 V)
CURVE B: 107H3-B (A) *
CURVE C: 107H2-A (A) (VIN = 1.2 V)
CURVE D: 107H2-B (A) *
PARAMETERS CONDITIONS
CURVE A: (17) 102L1-A (A) (VIN = 4.2 V)
CURVE B: (18) 102L1-B (A) • •
CURVE C: (20) 102L2-E (A) (VIN = 1.2 V)
PARAMETERS

CURVE A: (21) ICCH-A (A)
CURVE B: (22) ICCL-A (A)
CURVE C: (25) ICCZ-A (A)
DEVICE TYPE: 54HC74 (DUAL D-TYPE F/F)
MFG: TIX 5 DEVICES  TEST DATE 10-15-86
REF: JPL LOG 1374  DATE CODE 8801

PARAMETERS

CURVE A: (1) 10H  (A)
CURVE B: (2) 10L  (A)
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: TI 5 DEVICES TEST DATE 10-15-86
REF: JPL LOG 1374 DATE CODE 8601

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 10$^4$ 1.5 2
cor 10$^3$ 2.6 1.1 2.6 1.1 2.6 1.1 2.6 1.1 2.6

PARAMETER MEAN VALUE
-2.01 -2.07 -2.12 -2.17 -2.24
DEVICE TYPE: 54HC74 (DUAL D-TYPE F/F)
MFG: TIX 5 DEVICES TEST DATE 10-15-66
REF: JPL LOG 1374 DATE CODE 5801

PARAMETERS

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

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

TIME, hours

PRE-RAD

10^3 1.5 2. 3. 4. 5. 6. 10^4 1.5 2. 10^5 2. 4.610^3

PARAMETER MEAN VALUE
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rad(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>2.0E4</td>
<td>0.925</td>
</tr>
<tr>
<td></td>
<td>2.0E3</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>3.0E3</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>5.0E3</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>8.0E3</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>1.0E4</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>1.5E4</td>
<td>0.040</td>
</tr>
<tr>
<td></td>
<td>2.0E4</td>
<td>0.072</td>
</tr>
<tr>
<td></td>
<td>2.5E4</td>
<td>0.176</td>
</tr>
<tr>
<td></td>
<td>3.0E4</td>
<td>0.334</td>
</tr>
<tr>
<td></td>
<td>3.5E4</td>
<td>0.312</td>
</tr>
<tr>
<td></td>
<td>4.0E4</td>
<td>0.374</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOH(V) = +4.32X10^3
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE</th>
<th>DOSE, rads(SI)</th>
<th>CURVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOL (VCC=4.5V, IO=6MA) IN MV</td>
<td>VS DOSE</td>
<td></td>
</tr>
<tr>
<td>2.060</td>
<td>1.963 2.063 3.063 5.063 7.063 1.064 2.064 2.564 3.064</td>
<td></td>
</tr>
<tr>
<td>DOSE</td>
<td>4.564</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>67.26</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE: VOL (MV) = 1.52X10^12
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
<th>DOSE</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td></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>.0872 .0760 .0766 .0772 .0877 .1290 .2191 .5019 .9302 .8016 .9459</td>
<td>4.0E4</td>
<td>2.0E3</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE $I_{OH}(MA) = -6.63 \times 10^{10}$
DEVICE TYPE: 54HC394 CMOS OCTAL D-TYPE FF
MFG: NSC 5 DEVICES TEST DATE 11-13-83
REF: JPL LOG 1215 DATE CODE R6520

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

(4) I0L (VCC=4.5V,VO=.1MV) IN MA: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.9E0 1.0E3 2.0E3 3.0E3 5.0E3 7.0E3 1.0E4 1.5E4 2.0E4 2.5E4 3.0E4</td>
<td>.1513 .1359 .1442 .1347 .1396 .1473 .1916 .2912 .4325 .5371 .7346</td>
</tr>
<tr>
<td>DOSE</td>
<td>.4E0</td>
<td>1.440</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE I0L(MA) = 46.64X10\(^9\)
DEVICE TYPE: 54HC374 CMOS OCTAL D-TYPE F/F
MFG: NSC 5 DEVICES TEST DATE 11-13-85
REF: JPL LOG 1213 DATE CODE R8520

DOSE, rads(Si) Ca⁶⁰ Gammas

(3) I1H(VCC=6V, VIN=6V) IN NA: VS DOSE

<table>
<thead>
<tr>
<th>CURVE DOSE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0E0</td>
<td>.0000</td>
</tr>
<tr>
<td>1.0E3</td>
<td>.0000</td>
</tr>
<tr>
<td>2.0E3</td>
<td>.0000</td>
</tr>
<tr>
<td>3.0E3</td>
<td>.0000</td>
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<tr>
<td>5.0E3</td>
<td>.0000</td>
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<tr>
<td>7.0E3</td>
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<td>1.0E4</td>
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<tr>
<td>2.0E4</td>
<td>.0000</td>
</tr>
<tr>
<td>2.5E4</td>
<td>.0000</td>
</tr>
<tr>
<td>3.0E4</td>
<td>.0000</td>
</tr>
</tbody>
</table>

STD. DEV. | .0000 |
|---------|-------|

DOSE | 4.0E4 |
|      |       |
STD. DEV. | 126.9 |
|         |       |

INITIAL MEAN VALUE I1H(NA) = +9.99x10⁻¹
TRIBLE OF NORMAL STRNDRP, D DE'V I AT IONS CURVE DOSE.

<table>
<thead>
<tr>
<th>DOSE, rads(Si)</th>
<th>Ca60 Gammas</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0E3 1.0E3 2.0E3 3.0E3 5.0E3 7.0E3 1.0E4 1.5E4 2.0E4 2.5E4 3.0E4</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IIL(NA) = 46.80x10^-1
PARAMETERS

CURVE A:  
(1) VOH1-A (V)

CURVE B:  
(2) VOH1-B (V)

CONDITIONS

(1) OUT = -20 UA

(2) OUT = -20 UA

(3) OUT = -20 UA
DEVICE TYPE: 54H374 OCTAL D-TYPE FIF
MFG: NSC 3 DEVICES TEST DATE 3-24-67
REF: JPL LOG 1301 DATE CODE 8627

PARAMETERS

CURVE A:  (3) VOH2-A (V) (IOUT = -5.2 MA)
CURVE B:  (4) VOH2-B (V) * *

CONDITIONS

DOSE, rads(Si) Co60 Gammas
TIME, hours
DEVICE TYPE: 54HC374 OCTAL D-TYPE FF
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 8627

PARAMETER MEAN VALUE

DOSE, rads(SI) Co60 Gammas EOR TIME, hours

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>II-A</td>
<td>(VIN = VCC)</td>
</tr>
<tr>
<td>B</td>
<td>II-B</td>
<td>*</td>
</tr>
<tr>
<td>C</td>
<td>II-L-A</td>
<td>(VIN = GND)</td>
</tr>
<tr>
<td>D</td>
<td>II-L-B</td>
<td>*</td>
</tr>
</tbody>
</table>

5-52
DEVICE TYPE: 54HC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-67
REF: JPL LOG 1301 DATE CODE 8627

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(131) 102H1-A (A)</td>
<td>(VIN = 4.2 V)</td>
</tr>
<tr>
<td>B</td>
<td>(141) 102H1-B (A)</td>
<td>*</td>
</tr>
<tr>
<td>C</td>
<td>(151) 102H2-A (A)</td>
<td>(VIN = 1.2 V)</td>
</tr>
<tr>
<td>D</td>
<td>(161) 102H2-B (A)</td>
<td>*</td>
</tr>
</tbody>
</table>

DOSE, nads(Si) Co⁶⁰ Gammas vs. TIME, hours

PRE-RAD 5-53
DEVICE TYPE: 54H0374 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: (171) IOZL1-A (AI)  (VIN = 4.2 V)
CURVE B: (161) IOZL-B1 (AI)  "  "
CURVE C: (191) IOZL2-A (AI)  (VIN = 1.2 V)
CURVE D: (201) IOZL2-B (AI)  "  "

DOSE, rads(Si) Co60 Gammas  TIME, hours

PARAMETER MEAN VALUE

PRE-RAD  5.  6.  7.  8.  10^6  1.5  2.  3.  4.  5.  6  10^9  2.  4.6  10^12  2.4.6 10^12 2.
PARAMETERS

CURVE A: (21) ICCH-A (A)
CURVE B: (23) ICCA-A (A)
CURVE C: (25) ICCZ-A (A)
DEVICE TYPE: 54HC374 OCTAL D-TYPE FIFO
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 8627

PARAMETERS

CURVE A: (22) 1CCN-B (A)
CURVE B: (23) 1CCL-A (A)
CURVE C: (24) 1CCL-B (A)
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AMD 2 DEVICES TEST DATE 04-09-86
REF: JPL LOG 1250 DATE CODE 8531EHM

PARAMETERS

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

DOSE, rads(S) 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

10^0 10^1 10^2 10^3 10^4 10^5 10^6

5-57
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AMD  2 DEVICES  TEST DATE 04-09-86
REF: JPL LOG 1250  DATE CODE 8531EKM

PARAMETERS

CURVE A:  (2) IIL (VIL=OV) IN UA:

Dose, rad(Si)  2.5 MeV electrons


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

PARAMETER MEAN VALUE
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AMD 2 DEVICES TEST DATE 04-09-86
REF: JPL LOG 1250 DATE CODE 8531ENM

PARAMETERS

CURVE A: (3) IZS1 (INPUTS HIGH, IO MEASURED) IN NA:
CURVE B: (4) IZS2 (INPUTS LOW, IO MEASURED) IN NA:

PRE-RAD 10^4 1.5 2 3 4 5 6 10^5 1.5 2 3 4 5 6 10^6
19.62 4 13.79 66.71 302.13 255.05 207.96

DOSR, rads(Si) 2.5 MeV electrons

PARAMETER MEAN VALUE
PARAMETERS

CURVE A: 0.5 [IF3] (IFS3-IFS4) IN NA:
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AND 2 DEVICES TEST DATE 04-09-86
REF. JPL LOG 1230 DATE CODE 85312CMM

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 (-10.6V>VEE>-15V,DELTA 10 MEASURED) IN NA:
CURVE D: (9) PSS-2 (-15V>VEE>-16V,DELTA 10 MEASURED) IN NA:

DOSE, rads(S): 2.5 MeV electrons

PARAMETER MEAN VALUE

PRE-RAD 10^4 1.5 2. 3. 4. 5. 6. 10^6 1.5 2. 3. 4. 5. 6. 10^6
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:
DEVICE TYPE: AM6012A 12-BJT DAC

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

REF: JPL LG3 1250  DATE CODE 8531EMM

PARAMETERS

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

DOSE, rads(Si) 2.5 MeV electrons

PARAMETER MEAN VALUE

DEVICE TYPE: AM6012A 12-BJT DAC
MFG: AMD 2 DEVICES TEST DATE 04-09-86
REF: JPL LOG 1230 DATE CODE 6531LMM
PARAMETERS

CURVE A: 14) TPHL (MSE 50 POINT TO 10(-) 50 POINT) IN NA:
DEVICE TYPE: CD4013 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-13-66
REF: JPL LOG 1173 DATE CODE D407

PARAMETERS
CURVE A: (1) IOH (NA)
CURVE B: (2) IOL (NA)
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: (3) VTN1=ON (V)
CURVE B: (4) VTN2=ON (V)
CURVE C: (7) VTN5=ON (V)
CURVE D: (6) VTN4=ON (V)
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-15-66
REF: JPL LIG 1175 DATE CODE D407

PARAMETERS

CURVE A: (5) VTH5-OFF (V)
CURVE B: (6) VTH6-OFF (V)
CURVE C: (9) VTH12-OFF (V)
CURVE D: (10) VTH13-OFF (V)
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: (11) VTP3-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    3 DEVICES TEST DATE 09-15-86
REF: JPL LOG 1178    DATE CODE D407

PARAMETERS

CURVE A: (13) VTP5-ON (V)
CURVE B: (14) VTP6-ON (V)
CURVE C: (18) VTP12-ON (V)
CURVE D: (19) VTP13-ON (V)

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

PARAMETER MEAN VALUE

DOSERAD, 10^2 1.5 2 3 4.5 4 6 10^3 1.5 2 3 4.5 6 10^4 EOP

TIME, hours
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)

DOSE, rads (Si) Co60 Gammas COP TIME, hours
PRE-RAD 10^2 3 2 3 4 5 6 4.10^3 3 2 3 4 5 6 T 4.10^4 4 4.10^5 4 4.10^6 4
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-15-66
REF: JPL LOG 1:73 DATE CODE D407

PARAMETERS

DOSE, rads(S): Co60 Gammas
TIME, hours

PARAMETERS
CURVE A: [21] TPL4 (NS)
CURVE B: [22] TPL6 (NS)

5-72
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: (1) IGH IN NA:
CURVE B: (2) IQL IN NA:
PARAMETERS

- CURVE A: (3) VTN 1-ON (V)
- CURVE B: (4) VTN 2-ON (V)
- CURVE C: (7) VTN 8-ON (V)
- CURVE D: (8) VTN 9-ON (V)

CONDITIONS

- (B)IAS 15V
- -"
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)  * *
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-66
PEF: TPL LOG 1203 DATE CODE D407

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

DOSAGE, rads(Si) Co\(^{60}\) Gammas TIME, hours

PARAMETER MEAN VALUE

PRE-RAD 10\(^3\) 1.5 2. 3. 4. 5. 6. 7. 8. 10\(^1\) 2. 4.6\(\times10^2\) 2.

DOSE, rads(Si) Co\(^{60}\) Gammas TIME, hours
DEVICE TYPE: CD4011 QUAD NAND GATE

MFG: RCA  5 DEVICES  TEST DATE 09-17-86

REF: TPL LOG 1203  DATE CODE D407

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(13) VTP 5-ON [V] (BIAS GND)</td>
</tr>
<tr>
<td>B</td>
<td>(14) VTP 6-ON [V]</td>
</tr>
<tr>
<td>C</td>
<td>(17) VTP12-ON [V]</td>
</tr>
<tr>
<td>D</td>
<td>(18) VTP13-ON [V]</td>
</tr>
</tbody>
</table>
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:

DOSE, rads(S) Co60 Gammas
TIME, hours
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

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

PARAMETER MEAN VALUE

PRE-RAD 10\textsuperscript{3} 1.5 2. 3. 4. 5. 6. 7. 8. 9. 10\textsuperscript{4} 10\textsuperscript{5} 2. 4. 6.10\textsuperscript{5} 2. 4. 6.10\textsuperscript{6} 2.
DEVICE TYPE: CD4013 CMOS DUAL D F/F
MFG: SGS 5 DEVICES TEST DATE 06-22-85
REF: JPL 109 1176 DATE CODE 352V

![Graph showing the relationship between dose (in rads(Si)) and ICH(UA) for a 60Co Gamma, with points on the graph labeled A and B.]

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></td>
<td>0.023 1.063 2.6E-3 5.0E-3 1.0E-4 2.0E-4 3.0E-4 5.0E-4 1.0E-3</td>
<td>0.0098 .2770 .2345 .2596 .456 479.4 3272.9417 11111111</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE ICH(UA) = +2.13x10^6
DEVICE TYPE: CD4013 CMOS DUAL D FF
MFG: SGS 5 DEVICES TEST DATE 06-22-83
REF: JPL LOG 1176 DATE CODE 352Y

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

(2) IOL (VDD=15V) IN UA VS DOSE

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>0.0DE3 1.0DE3 2.1E3 5.0DE3 1.0E4 2.0E4 3.0E4 5.0E4 1.0E5</td>
<td>.0685 .1636 .1561 .2874 7.621 176.1 1102.5 267.1 1572.</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOL(UA) \( = 1.05 \times 10^8 \)
DEVICE TYPE: CD4013 CMOS DUAL D F/F
MFG: 865  5 DEVICES  TEST DATE 06-22-65
REF: JPL LOG 1176  DATE CODE 352Y

PRE-RAD

DOSAGE, rads(S.) Co60 Gamma

(3) VOUT= (10-6.6MA) IN V: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0E0 1.0E3 2.0E3 5.0E3 1.0E4 2.0E4 3.0E4 5.0E4 1.0E5</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>0416 .0447 .0570 .0652 .0447 .0570 .2162 .6544 XXXX</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOUT(V) = +1.36X10^5
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>0.000</td>
<td>1.0E-3</td>
<td>.5365</td>
</tr>
<tr>
<td>2.0E-3</td>
<td>5.0E-3</td>
<td>.3402</td>
</tr>
<tr>
<td>2.0E-4</td>
<td>2.0E-4</td>
<td>.3539</td>
</tr>
<tr>
<td>2.0E-4</td>
<td>4.0E-4</td>
<td>.3539</td>
</tr>
<tr>
<td>5.0E-4</td>
<td>4.0E-4</td>
<td>.2763</td>
</tr>
<tr>
<td>1.0E-4</td>
<td>1.0E-4</td>
<td>.6789</td>
</tr>
<tr>
<td>1.0E-4</td>
<td>2.0E-4</td>
<td>1.729</td>
</tr>
</tbody>
</table>

Initial mean value (IOH02(MA)) = 7.01 x 10^-9
DEVICE TYPE: CD4013 CMOS DUAL D FF
MFG: SGS 3 DEVICES TEST DATE 06-22-85
REF: JPL LOG 1176 DATE CODE 352V

PPE RAD

MEAN VOL02(MV)

DOSE, rads(Si) Co\textsuperscript{60} 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>0.960 1.063 2.123 5.063 1.064 2.064 3.064 5.064 1.065</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>2706 2977 5910 4077 1255 .5791 .5357 2.065 2.536</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOL02(MV) = +7.67X10\textsuperscript{-3}
**Device Type:** CD4013 CMOS DUAL D FF

**MFG:** SGS 3 DEVICES  TEST DATE 06-22-85

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

---

**Graph:**

- **Y-axis:** $I_{D102}(MA)$
- **X-axis:** Dose, rad$(S.i)$

**Equation:**

$(6) I_{D102}(V_D=1.5V)$ IN MA: $V_8$ DOSE

**Table:**

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rad$(S.i)$</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></td>
</tr>
<tr>
<td></td>
<td>2359 .2301 .1827 .1245 .1717 .1769 .1460 .3657 .4016</td>
<td></td>
</tr>
</tbody>
</table>

**Initial Mean Value $I_{D102}(MA) = +6.59x10^{12}$

* DEVICE PARAMETER FAILURE

---

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

PARAMETERS
CURVE A: (1)1001 (NA)
CURVE B: (2)1001 (NA)
DEVICE TYPE: CD4013 DUAL D FF
MFG: SGS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1204 DATE CODE 352V

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>VTN Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>VTN3-ON (V)</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>VTN5-ON (V)</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>VTN6-ON (V)</td>
</tr>
<tr>
<td>D</td>
<td>9</td>
<td>VTN10-ON (V)</td>
</tr>
</tbody>
</table>

* ANNEAL
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)
DEVELOPMENT: CD4013 DUAL D F/F
MFG: SGS 5 DEVICES TEST DATE 10-29-66
REF: JPL LOG 1204 DATE CODE 352Y

PARAMETERS
CURVE A: (19)TFQ1(NS)
CURVE B: (20)TFQ2(NS)
CURVE C: (21)TRQ1(NS)
CURVE D: (22)TRQ2(NS)

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

PARAMETER MEAN VALUE

5-89
DEVICE TYPE: CD4013 DUAL D F/F
MFG: SGS 5 DEVICES TEST DATE 10-29-66
REF: JPL LOG 1204 DATE CODE 352Y

PARAMETERS
CURVE A: 123TPLH01(NS)
CURVE B: 124TPLH02(NS)
CURVE C: 125TPLH01(NS)
CURVE D: 126TPLH02(NS)

5-90
DEVICE TYPE: CD4013 DUAL D FF
MFG: SSI  5 DEVICES  TEST DATE 10-29-86
REF: JPL LOG 1267  DATE CODE 8321

PARAMETERS

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

* ACCELERATED ANNEAL
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:  (3) VTN1-ON (V)
CURVE B:  (5) VTN5-ON (V)
CURVE C:  (6) VTN6-ON (V)
CURVE D:  (9) VTN10-ON (V)

DOSE, rads (Si) Ca<sup>60</sup> Gamma  TIME, hours

PARAMETER MEAN VALUE

5-92
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: (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: (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: SSS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1267 DATE CODE 8321

PARAMETERS
CURVE A: (23)TPHLO2(NS)
CURVE B: (24)TPHLO2(NS)
CURVE C: (25)TPHLO2(NS)
CURVE D: (26)TPHLO2(NS)
DEVICE TYPE: CD4013 DUAL D/F/F
MFG: SSS 5 DEVICES  TEST DATE 10-29-86
REF- TPL LOG 1266 DATE CODE 8321

PARAMETERS

CURVE A: \( \text{J10H(NN)} \)
CURVE B: \( \text{J21OL(NN)} \)
PARAMETERS

CURVE A: (3) VTN3-ON (VI)
CURVE B: (5) VTN5-ON (VI)
CURVE C: (6) VTN6-ON (VI)
CURVE D: (9) VTN10-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 1266 DATE CODE E321

PARAMETERS
CURVE A: (19)TFQ1(NS)
CURVE B: (20)TFQ2(NS)
CURVE C: (21)TRQ1(NS)
CURVE D: (22)TRQ2(NS)
DEVICE TYPE: CD4018 DUAL D FIF
MFG: SSS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1266 DATE CODE 8321

PARAMETERS
CURVE A: (23)TPLH03(NS)
CURVE B: (24)TPLH02(NS)
CURVE C: (25)TPLH01(NS)
CURVE D: (26)TPLH02(NS)
DEVICE TYPE: HCF4007 INVERTER
MFG: 88S  4 DEVICES  TEST DATE 09-13-88
REF: JPL LOG 1378  DATE CODE 98622Y

PARAMETERS

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

DOSE, rads(Si) Co60 Gammas
20 rads/sec Dose Rate
DEVICE TYPE: HC4007 INVERTER
MFG: SBS  4 DEVICES  TEST DATE 09-13-88
REF: JPL LOG 1378  DATE CODE 98822Y

PARAMETERS

CURVE A:  (4) DSP(6)-OFF  (A)
CURVE B:  (5) DSP(6)-ON  (A)
CURVE C:  (6) DSP(10)-OFF  (A)

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

2.600-10
2.597-10
2.594-10
2.191-10
1.987-10
1.784-10
1.701-10
1.376-10
1.175-10

PARAMETER MEAN VALUE

PRE-RAD  10^3  1.5  2.0  2.5  3.0  3.5  4.0  4.5  10^4

5-102
DEVICE TYPE: HCFO07 INVERTER
MFG: 8S8 4 DEVICES TEST DATE 09-13-88
REF: JPL LOG 1370 DATE CODE 98822Y

DOSE, rads(S) Co^{60} Gamma
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)

5-103
DEVICE TYPE: HCF4007 INVEPTER
MFG: SBS 4 DEVICES TEST DATE 09-13-86
REF: JPL LOG 1318 DATE CODE 96822Y

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

PARAMETERS
CURVE A: VTP(6)-OFF (V)
CURVE B: VTP(3)-ON (V)
CURVE C: VTP(10)-OFF(V)
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS  4 DEVICES  TEST DATE 09-15-88
REF: JPL 1379  DATE CODE 98822Y

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

PARAMETERS

CURVE A:
- (1) I\(\text{DSN}(6)\)-ON (A)

CURVE B:
- (2) I\(\text{DSN}(3)\)-OFF (A)

CURVE C:
- (3) I\(\text{DSN}(101)\)-ON (A)
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS  4 DEVICES  TEST DATE 09-15-86
REF: JPL LOG 1379  DATE CODE 98622Y

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 09-15-88
REF: JPL L08 1379 DATE CODE 96822Y

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

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

PARAMETER MEAN VALUE

PRE-RAD  \(10^3\) 2.5 2.0 1.5 1.0 0.5 0.0

Dose Rate Graph with curves A, B, and C.
DEVICE TYPE: HCF4007 INVERTER
MFG: S6S 4 DEVICES TEST DATE 09-15-88
REF: JPL LOG 1379 DATE CODE 96622V

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) IDSN(6)-ON (A)
CURVE B: (2) IDSN(3)-OFF (A)
CURVE C: (3) IDSN(10)-ON (A)
DEVICE TYPE: HCF4007 INVERTER
MFB: 888 4 DEVICES  TEST DATE 09-19-86
REF: JPL LOG 1380   DATE CODE 96622Y

PARAMETERS

CURVE A:  (4) ISDSP(6)-OFF  (A)
CURVE B:  (5) ISDSP(3)-ON  (A)
CURVE C:  (6) ISDSP(10)-OFF  (A)
DE/3C£ 3_PE: HCF4DG9

DEVICE TYPE: HCF4007 INVERTER
MFB: SBS 4 DEVICES TEST DATE 09-19-86
REF: JPL L08 1360 DATE CODE 96822Y

PARAMETERS

CURVE A: 71 VTN(6)-ON (V)
CURVE B: 3 VTN(3)-OFF (V)
CURVE C: 9 VTP(10)-ON (V)

PRE Rad
10^3

DOSE, rads(S) Co^60 Gammas

PARAMETER MEAN VALUE

A
B
C

5-111
DEVI CE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 09-19-86
REF: JPL LOG 1360 DATE CODE 96522Y

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

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

PARAMETERS

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

PARAMETER MEAN VALUE

PRE-RAD $10^3$  $10^4$  $10^5$

DOSAGE $10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ $10^0$ $10^1$ $10^2$ $10^3$ $10^4$
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS   4 DEVICES TEST DATE 09-19-86
REF: JPL L06 1366 DATE CODE 966229

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: SBG 4 DEVICES TEST DATE 09-19-88
REF: JPL LOG 1388 DATE CODE 96622Y

DOSE, rads(Si) Co60 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: HCF4007 INVERTER
MFG: SGS  4 DEVICES  TEST DATE 09-19-88
REF: JPL LOG 1386  DATE CODE 96822Y

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

PARAMETERS

CURVE A: \((\text{10})\text{ VTP(6)}-\text{OFF (V)}\)
CURVE B: \((\text{11})\text{ VTP(3)}-\text{ON (V)}\)
CURVE C: \((\text{12})\text{ VTP(10)}-\text{OFF (V)}\)
DEEP TYPE: 4C04007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 10-03-88
REF: JPL L08 1369 DATE CODE 98622Y

PARAMETERS
CURVE A: (1) IDSN(6)-ON (A)
CURVE B: (2) IDSN(3)-OFF (A)
CURVE C: (3) IDSN(10)-ON (A)
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 10-03-86
REF: JPL L08 1389 DATE CODE 98622Y

PARAMETERS

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

DEVO DE"V[O]E "YP[: HC\[0409 3N-\'\'ERTER"EI\'aE "IC\[00-86
\[3DL LOB \[313D\'TE CODE 988\'

PRE- RAD

DOSE, rads(Si) Co\[^{60}\] Gammas
0.0116 rads/sec Dose Rate
DEVICE TYPE: HGF4007 INVERTER
MFG: S8S 4 DEVICES TEST DATE 10-03-88
REF: JPL L08 1389 DATE CODE 98822Y

DOSE, rads(S) Co\textsuperscript{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)
PARAMETERS

CURVE A:  (10) VTP(6)-OFF (V)
CURVE B:  (11) VTP(3)-ON (V)
CURVE C:  (12) VTP(10)-OFF (V)
DEVICE TYPE: HCF4027 INVERTER
MFG: S86 4 DEVICES TEST DATE 10-10-88
REF: JPL LOB 1390 DATE CODE 96622Y

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

PARAMETERS

CURVE A: (4) IDSP(6)-OFF (A)
CURVE B: (5) IDSP(6)-ON (A)
CURVE C: (6) IDSP(10)-OFF (A)
DEVICE TYPE: HGF4007 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

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETER</th>
<th>STATEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>VTN(6)</td>
<td>ON (V)</td>
</tr>
<tr>
<td>B</td>
<td>VTN(3)</td>
<td>OFF (V)</td>
</tr>
<tr>
<td>C</td>
<td>VTP(10)</td>
<td>ON (V)</td>
</tr>
</tbody>
</table>

5-123
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 10-10-88
REF: JPL L08 1390 DATE CODE 98622Y

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

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(10) VTP(6)-OFF (V)</td>
</tr>
<tr>
<td>B</td>
<td>(11) VTP(3)-ON (V)</td>
</tr>
<tr>
<td>C</td>
<td>(12) VTP(10)-OFF (V)</td>
</tr>
</tbody>
</table>

5-124
DEVICE TYPE: HOF4012  DUAL D-TYPE F1F
MFG: SGS   6 DEVICES  TEST DATE 07-19-86
REF: JPL LOG 1360     DATE CODE 96614Y

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>ID</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>IQH</td>
<td>(A)</td>
</tr>
<tr>
<td>B</td>
<td>IQL</td>
<td>(A)</td>
</tr>
</tbody>
</table>

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

PARAMETER MEAN VALUE

PRE-RAD

TIME, hours

COR

10^{-3}  10^{-2}  10^{-1}  10^{0}  10^{1}  10^{2}  10^{3}  10^{4}  10^{5}  10^{6}  10^{7}  10^{8}  10^{9}  10^{10}
DEVICE TYPE: HGF4013  DUAL D-TYPE F/F
MFG: SGS  6 DEVICES  TEST DATE 07-19-88
REF: JPL LJD 1360  DATE CODE 98814Y

PARAMETERS

CURVE A:  \( \text{VTN}(3) \text{--ON} \)  (V)
CURVE B:  \( \text{VTN}(5) \text{--ON} \)  (V)
CURVE C:  \( \text{VTN}(6) \text{--ON} \)  (V)
CURVE D:  \( \text{VTN}(10) \text{--ON} \)  (V)

DOSE, rads(Si) Co\(^{60}\) Gammas
1.0 rads/sec Dose Rate
DEVICE TYPE: HCF4013 DUAL D-TYPE F/F
MFG: SGS 6 DEVICES TEST DATE 07-19-88
REF: JPL LOG 1360 DATE CODE 98814Y

CURVE A: (4) VTN(4)--OFF (V)
CURVE B: (7) VTN(8)--OFF (V)
CURVE C: (8) VTN(9)--OFF (V)
CURVE D: (10) VTN(12)--OFF (V)

PARAMETERS

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

DOR TIME, hours

PARAMETER MEAN VALUE

PRE-RAD

10$^3$ 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0

1.92
1.58
1.24
0.9
0.56
0.22
-0.13
-0.47

5-127
DEVICE TYPE: HOF1033  DUAL D-TYPE F/F
MFG: SGS & DEVICES  TEST DATE 07-19-86
REF: TPL LOG 1360  DATE CODE 96E14Y

PARAMETERS

CURVE A: (19) TPHLQ1 (S)
CURVE B: (20) TPHLQ1 (S)
CURVE C: (21) TPHLQ2 (S)
CURVE D: (22) TPHLQ2 (S)
DEVICE TYPE: HC4013 DUAL D-TYPE FF
MFG: SGS 6 DEVICES TEST DATE 08-06-88
REF: JPL LOG 1364 DATE CODE 96614V

PARAMETER MEAN VALUE

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

PARAMETERS

CURVE A: (1) IQH (A)
CURVE B: (2) IQL (A)
DEVICE TYPE: HOA4013 DUAL D-TYPE F1/F
MFG: SGS 6 DEVICES TEST DATE 08-08-88
REF: JPL LOG 1364 DATE CODE 96814Y

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>VTN(3)-ON (V)</td>
</tr>
<tr>
<td>B</td>
<td>VTN(6)-ON (V)</td>
</tr>
<tr>
<td>C</td>
<td>VTN(8)-OFF (V)</td>
</tr>
<tr>
<td>D</td>
<td>VTN(11)-OFF (V)</td>
</tr>
</tbody>
</table>

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

TIME, hours

PRE-RAD \(10^3\) 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 \(10^4\)
COR \(10^2\) \(4.610^1\) \(4.610^2\) \(4.610^3\)

PARAMETER MEAN VALUE

5-130
PARAMETERS
CURVE A: (1) IQH(NA)
CURVE B: (2) IQL(NA)
DEVICE TYPE: HF4013BE DUAL D FIF

MFG: SGS  S DEVICES  TEST DATE 9-25-66

PAR: DPL  LAB  1177  DATE CODE 3512W

PARAMETERS

CURVE A:  (3) VTN2-ON  (V)
CURVE B:  (5) VTN5-ON  (V)
CURVE C:  (6) VTNK-ON  (V)
CURVE D:  (9) VTN10-ON  (V)

Dose, rads (S) Co60 Gammas
DEVICE TYPE: HCF4013BE DUAL D F/F

MFG: SGS 5 DEVICES TEST DATE 9-25-86

PER: JPL LAB 1177 DATE CODE 332V

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>VTN4-OFF</td>
</tr>
<tr>
<td>B</td>
<td>VTN8-OFF</td>
</tr>
<tr>
<td>C</td>
<td>VTN9-OFF</td>
</tr>
<tr>
<td>D</td>
<td>VTN11-OFF</td>
</tr>
</tbody>
</table>

Dose, rads(Si) Co60 Gammas
DEVICE TYPE: HC04013BE DUAL D F/F
MFG: NSB 5 DEVICES TEST DATE 9-25-66
REF: JPL 108 1177 DATE CODE 352Y

PARAMETERS

CURVE A: (11) VIP3-OFF (V)
CURVE B: (12) VIP5-OFF (V)
CURVE C: (14) VIP6-OFF (V)
CURVE D: (17) VIP20-OFF (V)
PARAMETERS

CURVE A:  (19) TF1(NS)
CURVE B:  (20) TF2(NS)
CURVE C:  (21) TR1(NS)
CURVE D:  (22) TR2(NS)
DEDEVICE TYPE: MCF4013BE DUAL D F/F
MFR: SBS 3 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1177 DATE CODE 352Y

PARAMETERS
CURVE A: (23)TPH11(NS)
CURVE B: (24)TPH12(NS)
CURVE C: (25)TPH1(NS)
CURVE D: (26)TPH12(NS)
DEVICE TYPE: HCF4013BE DUAL D F/F
MFG: SJL 5 DEVICES TEST DATE 9-25-66
REF: JPL LOG 1178 DATE CODE 332Y

PARAMETERS
CURVE A: (1) IQP(NA)
CURVE B: (2) IQP(NA)

5-138
DEVICE TYPE: HC4013BE DUAL D F/F
MFG: SBS 5 DEVICES TEST DATE 9-25-86
REF: JPL L08 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)
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)
DEVICE TYPE: HCF4013BE DUAL D F/F
MFG: 98S 5 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1178 DATE CODE 352Y

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)

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

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

PARAMETER MEAN VALUE

-2.00 -1.91 -1.82 -1.72 -1.61 -1.53 -1.45 -1.34 -1.25
DEVICE TYPE: HCF4013BE DUAL D'IF
MFG: SGS 5 DEVICES TEST DATE 9-25-86
REF: JPL 808 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)

5-142
DEVICE TYPE: HC4013BE DUAL D FIF
MFG: 88S    3 DEVICES TEST DATE 9-25-86
REF: JPL L06 1176    DATE CODE 352Y

PARAMETERS
CURVE A: 191TF1(NS)
CURVE B: 201TF2(NS)
CURVE C: 211TR1(NS)
CURVE D: 221TR2(NS)
PARAMETERS

CURVE A: (23)TPLA1(NS)
CURVE B:  (24)TPLA2(NS)
CURVE C: (25)TPHL1(NS)
CURVE D: (26)TPHL2(NS)

DEVICE TYPE: HGF4019BE DUAL D11F
MFG: SGS 5 DEVICES  TEST DATE 9-25-86
REF: JPL LOG 1178  DATE CODE 352Y

DOSE, rads(Si) Co60 Gammas

PARAMETER MEAN VALUE

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

CURVE A:
CURVE B:
CURVE C:
CURVE D:
DEVICE TYPE: LF336BH FET INPUT OP AMP
MFG: NSC 3 DEVICES TEST DATE 12-06-85
REF: JPL L08 1168 DATE CODE HE448

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DLV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.9E4 1.0E4 2.0E4 3.0E4 5.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>----------------</td>
<td>-----------</td>
</tr>
<tr>
<td>STD. DLV.</td>
<td>1.200 1.237 1.220 1.268 0.9932 1.011 1.6604 1.777 3.646 13.69</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOS(MV) = -6.63X10^-3
DEVICE TYPE: LF336BH FET INPUT OP AMP
MFB: NSC 3 DEVICES TEST DATE 12-06-83
REF: JPL L08 1168 DATE CODE H8448

DOSE, rads(S; ) Co60 Gammas
(2) JOS (VOUT=0V) IN NA: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.0E0 1.0E4 2.0E4 3.0E4 4.0E4 5.0E4 6.0E4 7.0E4 8.0E4 9.0E4</td>
</tr>
<tr>
<td>STD. DV.</td>
<td>0.0007 0.0006 0.0042 0.0143 0.0165 0.0943 16.67 31.07 116.6 31.90</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE JOS(IN) = 3.79X10^-4
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></td>
<td>0.000</td>
<td>0.003</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IB(INA) = 47.61x10^-2
DEVICE TYPE: LF356BH FET INPUT OP AMP
MFG: NSC 3 DEVICES TEST DATE 12-06-85
REF: JPL LOG 1168 DATE CODE HE448

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

(4) +GAIN (VOUT=10V) IN DB VS DOSE

<table>
<thead>
<tr>
<th>TABLE OF NORMAL STANDARD DEVIATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURVE:</td>
</tr>
<tr>
<td>Dose</td>
</tr>
<tr>
<td>Std. Dev.</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE (GAIN[DB]) = +1.35X10^2
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>0.2E3</td>
<td>1.2E4 2.0E4 3.2E4 5.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6</td>
<td>2.115 2.281 2.519 2.232 1.624 2.116 2.395 16.33 24.37 17.05</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rad(Si) Co^60 Gammas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0E4 2.0E4 3.0E4 5.0E4 7.5E4</td>
</tr>
<tr>
<td>C</td>
<td>.2459 .2254 .2654 .2676 .4565</td>
</tr>
</tbody>
</table>
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>( \text{GAIN IN DB (10\text{MA LOAD}, 4\text{10V})} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;UPV&quot;</td>
<td>( 1.0 \times 10^4 )</td>
<td>( 2.0 \times 10^4, 3.0 \times 10^4, 5.0 \times 10^4, 7.5 \times 10^4 )</td>
</tr>
<tr>
<td>&quot;DP&quot;</td>
<td>( 1.0 \times 10^4 )</td>
<td>( 2.5 \times 10^4, 2.769 \times 10^4, 3.706 \times 10^4, 2.207 \times 10^4, 2.907 \times 10^4 )</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE: \( \text{GAIN (DB)} = 1.0 \times 10^2 \)
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Dose (rad(S))</th>
<th>Gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>1.0E4 2.0E4 3.0E4 5.0E4 7.5E4</td>
<td>3.0E4 3.2E4 3.3E4 3.6E4 3.8E4</td>
</tr>
<tr>
<td>L</td>
<td>1.0E3 4.0E4 3.6E4 3.2E4 3.3E4 3.6E4 3.8E4</td>
<td>3.0E4 3.2E4 3.3E4 3.6E4 3.8E4</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE -GAIN(DB) = 1.23X10^4
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-85
REF: JPL LOG 1150 DATE CODE 8437

DOSE, rads(Si) Co₆₀ Gammas

(1)VOS (R=50 OHMS) IN MV VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE (rads(Si))</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.002 1.0E4 2.0E4 3.0E4 5.0E4</td>
<td>0.242 .0261 .2637 .6557 17.01</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOS(MV) = -1.26X10⁻²
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-85
REF: JPL LOG 1150 DATE CODE 8437

![Graph showing mean $I_{OS}$ vs dose. The graph plots $I_{OS}$ (in PA) against dose in rads (Si) for Co$^{60}$ Gamma rays. A table below lists the dose and corresponding standard deviations.](image)

**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>2500</td>
<td>0.0E0 1.0E4 2.0E4 3.0E4 5.0E4</td>
<td>31.07 66.58 93.39 258.6 9757.</td>
</tr>
</tbody>
</table>

**INITIAL MEAN VALUE $I_{OS}$ (PA) = $-1.89 \times 10^4$**
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-85
REF: JPL LOG 1150 DATE CODE 8437

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S1)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9E4</td>
<td>1.0E4</td>
<td>2.0E4</td>
</tr>
<tr>
<td>3.0E4</td>
<td>3.0E4</td>
<td>5.0E4</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE (Iß(IN)) = +6.21X10^4
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-85
REF: JPL LOG 1150 DATE CODE 8437

DOSE, rads(Si) Co-60 Gammas
(4) + GAIN (VOUT=10V, PL=2X0HMS) IN DB VS 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 1.0E4 2.0E4 3.0E4 5.0E4</td>
<td>3.261 11.06 12.06 1.160 2.466</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE + GAIN(10^4) = 47.35X10^4

5-158
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-65
REF: JPL LUB 1150 DATE CODE 6437

![Graph showing dose vs gain for Co<sup>60</sup> gammas.]

**Table of Normal Standard Deviations**

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S:)</th>
<th>Dose (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.6E4 1.9E4 2.9E4 3.9E4 5.9E4</td>
<td>0.9E4 2.9E4 7.9E4 1.9E4 3.9E4</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>1.768 2.322 7.476 .7661 .7135</td>
<td></td>
</tr>
</tbody>
</table>

**Initial Mean Value (Gain) = ±5.45x10<sup>-1</sup>**
DEVICE TYPE: MC14007 D COMPLIMENTARY W/JINVER
MFG: MOT  6 DEVICES  TEST DATE 09-07-88
REF: JPL LOG 1376  DATE CODE FR 8705

PARAMETERS
CURVE A:  (1) IDS(6)-ON (A)
CURVE B:  (2) IDS(3)-OFF (A)
CURVE C:  (3) IDS(10)-ON (A)
DEVICE TYPE: MC14807 D COMPLIMENTARY WINVER
MFG: MOT 6 DEVICES TEST DATE 09-07-86
REF: JPL LOG 1376 DATE CODE FR 6705

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

PARAMETERS
CURVE A: 1DSP(6)-OFF (A1)
CURVE B: 1DSP(3)-ON (A1)
CURVE C: 1DSP(10)-OFF (A1)
DEVICE TYPE: MC14007 D COMPLIMENTARY W/JNVER
MFG: MOT 6 DEVICES TEST DATE 09-07-88
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)

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

TIME, hours

PRE-RAD

PARAMETER MEAN VALUE

DOSERAD

TIME, hours

10^3 1.5 2. 3. 4. 5. 6. 8. 10^4 1.5 2. 10^6 2. 4.610^6 2. 4.610^3

5-162
**DEVICE TYPE:** MC34007 D COMPLIMENTARY WJINVER
**MFG:** MOT 6 DEVICES TEST DATE 09-07-88
**REF:** JPL LOG 13'76 DATE CODE FR 8705

---

**PARAMETERS**

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>VTP(6)-OFF (V)</td>
</tr>
<tr>
<td>B</td>
<td>VTP(3)-ON (V)</td>
</tr>
<tr>
<td>C</td>
<td>VTP(10)-OFF (V)</td>
</tr>
</tbody>
</table>

---

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

0.5 rads/sec Dose Rate

---

**TIME, hours**

---

**PRE-RAD**

---

**EOR**

---

---

---

---

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

PARAMETERS

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

20 rads/sec Dose Rate

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

PRE-RAD  $10^3$  1.5  2  3  4  $10^4$  1.5  2  3  4  $10^5$  1.5  2  3  4  $10^6$  1.5  2  3  4  4.6

EOR  $10^3$  1.5  2  3  4  $10^4$  1.5  2  3  4  $10^5$  1.5  2  3  4  $10^6$  1.5  2  3  4  4.6
DEVICE TYPE: MC14007 D COMPLEMENTARY W/NVER
MFG: MOT 6 DEVICES TEST DATE 06-17-85
REF: JPL LOG 1377 DATE CODE FR 8705

PARAMETER MEAN VALUE

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

PARAMETERS

CURVE A: (4) DSP(6)-ON (A)
CURVE B: (5) DSP(3)-OFF (A)
CURVE C: (6) DSP(10)-OFF (A)
DEVICE TYPE: MC14007 D COMPLIMENTARY WI/INVER
MFG: MOT 6 DEVICES TEST DATE 06-17-88
REF: JPL LOG 13777 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)

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

PRE-RAD 10$^3$ 1.5 2. 3. 4. 5. 6. 8. 10$^4$ 1.5 2. 3. 4. 10$^2$ 1.6 2. 4.6 10$^4$ 2. 4.6.

PARAMETER MEAN VALUE

-8.17 -6.95 -5.74 -4.32 -2.09 -1.58 -0.34
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: C101 VTP(6)-ON (V1)
CURVE B: C111 VTP(3)-OFF (V1)
CURVE C: C121 VTP(10)-OFF(V1)
DEVICE TYPE: MC14007 CMOS INVERTER
MFG: NOT 5 DEVICES TEST DATE 10-10-88
REF: JPL L.OG 1392 DATE CODE FF 87361

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

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IDSN</th>
<th>STATE</th>
<th>CODE</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>ON</td>
<td>(A)</td>
</tr>
<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>

5-168
DETEC TYPE: MC14007 CMOS INVERTER
MOF: MOT 5 DEVICES TEST DATE 10-10-88
REF: JPL LOG 1392 DATE CODE FF 87361

PARAMETERS
CURVE A: (4) IDSP(6)-ON (A)
CURVE B: (5) IDSP(3)-OFF (A)
CURVE C: (6) IDSP(10)-OFF (A)
DEVICE TYPE: MC14007 CMOS INVERTER
MFG: MOT 5 DEVICES TEST DATE 10-10-88
REF: JPL L08 1392 DATE CODE FF 87361

PARAMETERS

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

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

PRE-RAD

PARAMETER MEAN VALUE

1.05
1.12
1.19
1.28
1.32
1.39
1.53
1.59

0-5
DEVICE TYPE: MC14007 CMOS INVERTER
MFG: M/JT 5 DEVICES TEST DATE 10-10-88
REF: JPL L08 1392 DATE CODE FF 67361

DOSE, rads(SL) Co\(^{60}\) Gammas
0.0156 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)
DEVI CE TYPE: OP-27 OP AMP
MFG: BUB 5 DEVICES TEST DATE 05-15-86
REF: JPL LOG 1182 DATE CODE 8503

DEVICE: TYPE: OP-27 OP AMP
MFG: BUB 5 DEVICES TEST DATE 05-15-86
REF: JPL LOG 1182 DATE CODE 8503

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4. 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E7 3.0E7 6.0E7 2.4E1</td>
<td></td>
</tr>
<tr>
<td>.0034 .0030 .0021 .0059 .0042 .0272 .1209 .1076 .1042 .1033 .1017</td>
<td></td>
</tr>
</tbody>
</table>

DOSE/HOURS: 7.2E1 2.4E2 7.2E2 2.4E3
STD. DEV.: 1.066 1.122 1.196 1.161

MEAN ΔVOS (MV) X10-3

DOSE, rad(Si) Co60 Gammas
TIME, hours

(1) ΔVOS IN MV VS DOSE

5-172
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>2.0E4</td>
</tr>
<tr>
<td>1.5E5</td>
<td>1.0E6</td>
</tr>
<tr>
<td>3.0E5</td>
<td>2.0E6</td>
</tr>
<tr>
<td>6.0E5</td>
<td>1.0E7</td>
</tr>
<tr>
<td>1.0E6</td>
<td>2.0E7</td>
</tr>
<tr>
<td>3.0E7</td>
<td>3.0E8</td>
</tr>
<tr>
<td>6.0E8</td>
<td>2.0E9</td>
</tr>
<tr>
<td>1.0E9</td>
<td>3.0E10</td>
</tr>
<tr>
<td>3.0E10</td>
<td>6.0E11</td>
</tr>
</tbody>
</table>

STD. DEV. | 0.2925 0.5472 1.24 2.126 3.673 6.126 12.33 12.97 12.51 12.67

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2E1</td>
<td>2.4E2</td>
</tr>
<tr>
<td>7.2E2</td>
<td>2.4E3</td>
</tr>
</tbody>
</table>

STD. DEV. | 16.45 13.96 13.13 13.75
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>1.0E6</td>
<td>2.0E6</td>
<td>1.0E0</td>
</tr>
<tr>
<td>3.0E0</td>
<td>8.0E0</td>
<td>2.4E1</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>1.234</td>
<td>1.279</td>
</tr>
<tr>
<td>1.046</td>
<td>9.343</td>
<td>16.69</td>
</tr>
<tr>
<td>21.17</td>
<td>24.66</td>
<td>24.94</td>
</tr>
<tr>
<td>24.64</td>
<td>24.30</td>
<td>25.05</td>
</tr>
<tr>
<td>DOSE/HOURS</td>
<td>7.2E1</td>
<td>2.4E2</td>
</tr>
<tr>
<td>7.2E2</td>
<td>2.4E3</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>23.33</td>
<td>20.96</td>
</tr>
<tr>
<td>16.66</td>
<td>11.93</td>
<td></td>
</tr>
</tbody>
</table>
DETECNE TYPE: OP-27 OP AMP
MFG: SUB 5 DEVICES TEST DATE 05-15-86
REF: JPL LOG 1162 DATE CODE 8503

![Graph showing the relationship between dose and time.](image)

**Table of Normal Standard Deviations**

<table>
<thead>
<tr>
<th>Dose/Hours</th>
<th>Time, Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>2.0E6</td>
</tr>
<tr>
<td>7.5E4</td>
<td>1.422</td>
</tr>
<tr>
<td>1.5E5</td>
<td>3.192</td>
</tr>
<tr>
<td>3.0E5</td>
<td>3.263</td>
</tr>
<tr>
<td>6.0E5</td>
<td>3.069</td>
</tr>
<tr>
<td>9.0E5</td>
<td>2.389</td>
</tr>
<tr>
<td>1.2E6</td>
<td>2.662</td>
</tr>
<tr>
<td>1.5E6</td>
<td>2.514</td>
</tr>
<tr>
<td>1.8E6</td>
<td>2.296</td>
</tr>
</tbody>
</table>

**Initial Mean Value +Gain(DB) = +1.24x10^2**

5-175
DEVICE TYPE: OP-27 OP AMP
MFG: SUB 5 DEVICES TEST DATE 05-15-86
REF: JPL LOG 1162 DATE CODE 8503

DOSE, rads(Si) Co60 Gammas
TIME, hours

(5) -GAIN (1k LOAD=10MA, -10V) IN DEB VS DOSE

<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>6.0E5</td>
<td>1.2E6</td>
<td>2.0E6</td>
</tr>
<tr>
<td>3.0E6</td>
<td>1.0E6</td>
<td>1.79</td>
</tr>
<tr>
<td>6.0E6</td>
<td>1.0E6</td>
<td>1.036</td>
</tr>
<tr>
<td>1.0E7</td>
<td>2.0E7</td>
<td>7.2E1</td>
</tr>
<tr>
<td>2.0E7</td>
<td>2.4E7</td>
<td>7.2E2</td>
</tr>
<tr>
<td>2.4E8</td>
<td></td>
<td>2.4E3</td>
</tr>
</tbody>
</table>

STD. DEV.:

INITIAL MEAN VALUE -GAIN(DB) = +1.23x10^2
DEVICE TYPE: OP-27 OP AMP
MFG: LTC 5 DEVICES TEST DATE 05-15-66
REF: JPL LOG 1142 DATE CODE 6576

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>3.0E4</th>
<th>7.5E4</th>
<th>1.5E5</th>
<th>3.0E5</th>
<th>1.0E6</th>
<th>4.6E1</th>
<th>7.2E1</th>
<th>2.4E2</th>
<th>7.2E2</th>
<th>2.4E3</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>1.539</td>
<td>.0736</td>
<td>.2284</td>
<td>3.697</td>
<td>5.768</td>
<td>.1860</td>
<td>.1369</td>
<td>.0811</td>
<td>.0457</td>
<td>.0314</td>
</tr>
</tbody>
</table>

DOSE (rads(S)) Co$^{60}$ Gamma | TIME (hours) | MEAN $\Delta$VOS (MV) x 10$^{-4}$ | EOR

(1) $\Delta$VOS IN MV VS DOSE
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
</tr>
<tr>
<td>1.5E5</td>
<td>3.0E5</td>
</tr>
<tr>
<td>1.0E6</td>
<td>4.6E1</td>
</tr>
<tr>
<td>7.2E1</td>
<td>2.4E2</td>
</tr>
<tr>
<td>7.2E2</td>
<td>2.4E3</td>
</tr>
</tbody>
</table>

| STD. DEV.  | 19.49 21.19 104.9 72.62 58.70 40.00 15.17 6.633 3.742 6.366 |

* MEASUREMENT PROBLEM
DEVICE TYPE: OP-27 OP AMP
MFG: LTC 5 DEVICES TEST DATE 05-15-66
REF: JPL LOG 1142 DATE CODE 8578

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9E4</td>
<td>7.5E4</td>
<td>1.5E5</td>
</tr>
<tr>
<td>3.9E5</td>
<td>4.6E1</td>
<td>7.2E1</td>
</tr>
<tr>
<td>1.0E2</td>
<td>7.2E2</td>
<td>2.4E3</td>
</tr>
</tbody>
</table>

3.9E4 1.5E5 4.6E1 7.2E1 2.4E3 91.44
DEVICE TYPE: OP-27 OP AMP
MFG: LTC 5 DEVICES TEST DATE 05-15-66
REF: JPL LOG 1142 DATE CODE 6576

(4) +GAIN (1K LOAD=10mA, +10V) IN DEG VS DOSE

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>4.6E1</td>
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<tr>
<td>1.5E5</td>
<td>2.4E3</td>
</tr>
<tr>
<td>3.0E5</td>
<td>2.4E3</td>
</tr>
<tr>
<td>1.0E6</td>
<td>1.0E6</td>
</tr>
</tbody>
</table>

STD. DEV.0 2.062 4.910 1.559 13.16 12.91 10.55 5.424 4.544 10.44

INITIAL MEAN VALUE +GAIN(DB) = +1.31X10^2

5-180

C.3
DEVICE TYPE: OP-27 OP AMP
MFG: LTC 5 DEVICES TEST DATE 05-15-86
REF: JPL LOG 1142 DATE CODE 6578

DOSE, rads(Si) Co60 Gammas TIME, hours

(5) -GAIN (1k LOAD:104A, -10V) IN DBS VS DOSE

<table>
<thead>
<tr>
<th>I&lt;sub&gt;i&lt;/sub&gt;</th>
<th>DOSE, rads(Si)</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0 mA</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 1.0E6 4.6E1 7.2E1 2.4E2 7.2E2 2.4E3</td>
<td>2.067 10.31 ***** ***** ***** ***** ***** 3.314 5.933</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE -GAIN (dB) = +1.49x10<sup>4</sup>

5-181
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
<th>DOSE, rads(S;)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
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<td>1.0E6</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td>7.0E4</td>
<td>2.0E6</td>
<td>0.024</td>
<td></td>
</tr>
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<td>1.5E5</td>
<td>3.0E6</td>
<td>0.0041</td>
<td></td>
</tr>
<tr>
<td>3.0E5</td>
<td>4.0E6</td>
<td>0.0063</td>
<td></td>
</tr>
<tr>
<td>6.0E5</td>
<td>5.0E6</td>
<td>0.0015</td>
<td></td>
</tr>
<tr>
<td>1.0E6</td>
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<td>0.0017</td>
<td></td>
</tr>
<tr>
<td>2.0E6</td>
<td>7.0E6</td>
<td>0.0089</td>
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</tr>
<tr>
<td>3.0E6</td>
<td>8.0E6</td>
<td>0.0080</td>
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</tr>
<tr>
<td>4.0E6</td>
<td>9.0E6</td>
<td>0.0075</td>
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<td>5.0E6</td>
<td>1.0E7</td>
<td>0.0075</td>
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<tr>
<td>6.0E6</td>
<td>1.0E7</td>
<td>0.0070</td>
<td></td>
</tr>
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</table>

(1) VOS IN MV VS DOSE
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>
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<td>1.5E5</td>
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<td>1.5E5</td>
<td>3.0E5</td>
<td>6.0E5</td>
</tr>
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<td>2.0E6</td>
<td>1.0E6</td>
<td>3.0E6</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.0E6</td>
<td>6.0E6</td>
</tr>
<tr>
<td>2.4E1</td>
<td>5.0E3</td>
<td>17.55</td>
</tr>
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<td>2.5E4</td>
<td>3.5E3</td>
<td>20.55</td>
</tr>
<tr>
<td>3.0E5</td>
<td>2.5E3</td>
<td>25.45</td>
</tr>
<tr>
<td>3.0E5</td>
<td>3.0E3</td>
<td>32.97</td>
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<tr>
<td>3.0E5</td>
<td>3.0E3</td>
<td>37.64</td>
</tr>
<tr>
<td>3.0E5</td>
<td>3.0E3</td>
<td>39.63</td>
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</tbody>
</table>

STD. DEV.:

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

<table>
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<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.91</td>
<td>7.1</td>
</tr>
<tr>
<td>10.21</td>
<td>2.4</td>
</tr>
<tr>
<td>12.51</td>
<td>3.6</td>
</tr>
<tr>
<td>14.60</td>
<td>3.8</td>
</tr>
<tr>
<td>17.10</td>
<td>4.0</td>
</tr>
<tr>
<td>20.55</td>
<td>4.1</td>
</tr>
<tr>
<td>25.45</td>
<td>4.2</td>
</tr>
<tr>
<td>32.97</td>
<td>4.3</td>
</tr>
<tr>
<td>39.63</td>
<td>4.4</td>
</tr>
</tbody>
</table>

(2) I0S IN NA VS DOSE
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(Si) Co$^{60}$ Gammas</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
<td>1.9E3</td>
</tr>
<tr>
<td>3.0E6</td>
<td>6.0E6</td>
<td>1.0E6</td>
</tr>
<tr>
<td>3.0E1</td>
<td>8.0E1</td>
<td>2.0E1</td>
</tr>
<tr>
<td>3.0E2</td>
<td>6.0E2</td>
<td>2.0E2</td>
</tr>
<tr>
<td>2.4E1</td>
<td>1.0E1</td>
<td>2.0E1</td>
</tr>
<tr>
<td>2.4E2</td>
<td>1.0E2</td>
<td>2.0E2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>13.07</td>
</tr>
<tr>
<td>3.0E6</td>
<td>22.47</td>
</tr>
<tr>
<td>3.0E1</td>
<td>28.66</td>
</tr>
<tr>
<td>3.0E2</td>
<td>22.74</td>
</tr>
<tr>
<td>2.4E1</td>
<td>34.64</td>
</tr>
<tr>
<td>2.4E2</td>
<td>40.35</td>
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<tr>
<td>1.0E1</td>
<td>52.36</td>
</tr>
<tr>
<td>1.0E2</td>
<td>66.74</td>
</tr>
<tr>
<td>2.0E1</td>
<td>82.60</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2E1</td>
<td>54.90</td>
</tr>
<tr>
<td>2.4E2</td>
<td>23.11</td>
</tr>
<tr>
<td>7.2E2</td>
<td>19.16</td>
</tr>
</tbody>
</table>
DEVICE TYPE: OP-27 OP AMP
MFG: MPS 4 DEVICES  TEST DATE 06-11-86
REF: JPL LOG 1147  DATE CODE 6350

DE'7iCE TYPE: OP-27 OP AMP
MFG: MPS 4 DEVICES  TEST DATE 06-11-86
REF: JPL LOG 1147  DATE CODE 6350

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>7.3E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E6 3.0E6 8.0E6 2.4E1</td>
<td></td>
</tr>
<tr>
<td>7.2E1</td>
<td>2.4E2 7.2E2</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE +GAIN(DB) = +1.26x10^2

5-185
DEVICE TYPE: UP-27 UP AMP
MFG: MPS 4 DEVICES TEST DATE 06-11-66
REF: JPL LOG 1147 DATE CODE E350

DOSE, rads(Si) Co60 Gammas   TIME, hours
E - GAIN (1K LOAD=10MA, -10V) IN DB VS DOSE

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>3.0E+2</th>
<th>7.5E+2</th>
<th>1.5E+3</th>
<th>3.0E+3</th>
<th>6.0E+3</th>
<th>1.0E+4</th>
<th>2.0E+4</th>
<th>1.0E+5</th>
<th>3.0E+5</th>
<th>6.0E+5</th>
<th>2.4E+6</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>.4139</td>
<td>.9143</td>
<td>.0000</td>
<td>2.535</td>
<td>2.535</td>
<td>1.704</td>
<td>1.441</td>
<td>1.119</td>
<td>.9329</td>
<td>1.119</td>
<td>1.119</td>
</tr>
<tr>
<td>DOSE/HOURS</td>
<td>7.2E2</td>
<td>2.4E2</td>
<td>7.2E2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>1.500</td>
<td>1.500</td>
<td>1.249</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE -GAIN(DB) = +1.26X10^2

5-186
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 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E0 3.0E0 6.0E0 2.4E1</td>
<td>.0130 .0434 .1657 .1567 .1665 .2199 .1162 .1063 .0980 .0693 .0583</td>
</tr>
<tr>
<td>.0489</td>
<td>.0277 .0225</td>
<td>.0289 .0277 .0225</td>
</tr>
</tbody>
</table>

DEVICE TYPE: OP-27 OP AMP
MFG: Ray 5 DEVICES TEST DATE 06-11-86
REF: JPL LOG 1168 DATE CODE 8230

1) VOS IN MV VS DOSE
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
<td>1.5E3</td>
</tr>
<tr>
<td>3.0E5</td>
<td>6.0E5</td>
<td>1.2E6</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.0E6</td>
<td>3.0E6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>62.67</td>
<td>195.5</td>
<td>286.4</td>
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<tr>
<td>287.9</td>
<td>147.2</td>
<td>228.0</td>
</tr>
<tr>
<td>221.6</td>
<td>226.0</td>
<td>254.1</td>
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<tr>
<td>266.4</td>
<td>313.5</td>
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<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2E1</td>
<td>2.4E2</td>
<td>7.2E2</td>
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<table>
<thead>
<tr>
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<th>TIME, hours</th>
<th>STD. DEV.</th>
</tr>
</thead>
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<tr>
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<td>266.3</td>
<td>250.9</td>
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</table>
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
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<th>DOSE, rads(Si)</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5E4</td>
<td>3.5E3, 3.5E3</td>
<td>2.0E6, 2.0E6</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>166.1, 128.1</td>
<td>414.9, 97.92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>7.2E2</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>166.1</td>
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</table>

DETF: 5 DEVICES  TEST DATE 06-11-86
REF: JPL LOG 11/86  DATE CODE 5420
MFG: DAY 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>TIME, hours</th>
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</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>1.131</td>
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<tr>
<td>7.5E4</td>
<td>1.264</td>
</tr>
<tr>
<td>1.5E5</td>
<td>2.366</td>
</tr>
<tr>
<td>3.0E5</td>
<td>2.737</td>
</tr>
<tr>
<td>6.0E5</td>
<td>2.771</td>
</tr>
<tr>
<td>1.0E6</td>
<td>2.936</td>
</tr>
<tr>
<td>2.0E6</td>
<td>2.909</td>
</tr>
<tr>
<td>4.0E6</td>
<td>2.610</td>
</tr>
<tr>
<td>1.0E7</td>
<td>0.6159</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
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<tr>
<td>7.5E4</td>
<td>1.603</td>
</tr>
<tr>
<td>1.5E5</td>
<td>2.737</td>
</tr>
<tr>
<td>3.0E5</td>
<td>2.771</td>
</tr>
<tr>
<td>6.0E5</td>
<td>2.936</td>
</tr>
<tr>
<td>1.0E6</td>
<td>2.909</td>
</tr>
<tr>
<td>2.0E6</td>
<td>2.610</td>
</tr>
<tr>
<td>4.0E6</td>
<td>0.6159</td>
</tr>
<tr>
<td>1.0E7</td>
<td>1.603</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE +GAIN(DB) = +1.24X10^2

5-190
DEVICE TYPE: OP-27 OP AMP
MFG. DATE 5 DEVICES TEST DATE 06-11-86
REF: JPL LOG 1166 DATE CODE 6230

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE (rads(Si)) Co60 Gammas</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose/Hours</td>
<td></td>
</tr>
<tr>
<td>3.0E4</td>
<td>3.0E3</td>
</tr>
<tr>
<td>6.0E5</td>
<td>6.0E5</td>
</tr>
<tr>
<td>1.0E6</td>
<td>1.0E6</td>
</tr>
<tr>
<td>2.0E6</td>
<td>2.0E6</td>
</tr>
<tr>
<td>1.0E7</td>
<td>1.0E7</td>
</tr>
<tr>
<td>3.0E7</td>
<td>3.0E7</td>
</tr>
<tr>
<td>6.0E8</td>
<td>6.0E8</td>
</tr>
<tr>
<td>2.4E9</td>
<td>2.4E9</td>
</tr>
</tbody>
</table>


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

5-191
DEVICE TYPE: OPA111 FET-INPUT OP-AMP
MF#: DUB 5 DEVICES TEST DATE 10-17-85
REF: JPL LOG 1196 DATE CODE 6449

DOSE, rads(Si) 2.5 MeV electrons

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>0.050 1.565</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td>3.065 6.065</td>
<td>0.075</td>
</tr>
<tr>
<td></td>
<td>1.066 3.066</td>
<td>0.2361</td>
</tr>
<tr>
<td></td>
<td>1.067 3.067</td>
<td>0.4535</td>
</tr>
</tbody>
</table>

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

5-192
DEVICE TYPE: OPAL111 FET-INPUT OP-AMP

REF. SUB 5 DEVICES TEST DATE 10-17-65

DATE CODE 6449

DOSE, rads(Si) 2.5 MeV electrons

12) I08 IN PA VS DOSE

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>0.003 1.0x10^3 3.0x10^3 6.0x10^3 1.0x10^4 3.0x10^4 1.0x10^5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.163 .2466 .6662 .5692 .1676 .9360 2.971</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE I08(PA) = +1.60X10^2

5-193
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>2.5 MeV electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.000</td>
<td>1.5X10^3</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>4523</td>
<td>2.014</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE I2(PA) = +1.10X10^-3

5.194
### Device Type: OPA111 FET-Input Op-Amp

**Wsb: 5 Devices Test Date 10-09-85**

**Ref: JPL L08 1199 Date Code 8449**

#### 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>0.000 1.0E-5 3.0E-5 6.0E-5 1.0E-6 3.0E-6 1.0E-7</td>
</tr>
<tr>
<td>STD. DLV.</td>
<td>0.000 .1696 .3524 .5660 .7006 .6302 .7916</td>
</tr>
</tbody>
</table>

**Initial Mean Value VOS(MV) = -6.61x10^-5**

---

**Graph:**
- X-axis: 10^-6 to 10^-7
- Y-axis: 0 to 73
- Data points labeled A.
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 1.0E5 3.0E5 6.0E5 1.0E6 3.0E6 1.0E7</td>
<td>.3461 .2569 .5916 .5164 .1865 1.051 1.172</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE 10S(PA) = ±6.86X10⁻¹
DEVICE TYPE: OPA111 FET-INPUT OP-AMP
REG: BUE 9 DEVICES TEST DATE 10-09-65
REP: JPL LOG 1199 DATE CODE 6449

Dose, rads(Si) Co60 Gamma
(3) IE IN PA: VS Dose

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>0.200 1.25 2.25 3.25 6.25 1.066 3.066 1.067</td>
<td>3.621 5.341 13.35 12.69 66.61 74.61</td>
</tr>
</tbody>
</table>

Initial mean value I2(100) = +1.15X10^-3

5-197
APPENDIX A

VENDOR IDENTIFICATION CODE LIST
## VENDOR IDENTIFICATION CODE LIST

<table>
<thead>
<tr>
<th>Vendor 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>
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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
IH   Input Current High
IL   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