Total-Dose Radiation Effects
Data for Semiconductor Devices
1989 Supplement

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Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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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).
JPL/NASA GROUND TEST RADIATION DATA BANK

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 down load 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 DECnet(SPAN):

If your facility has a VAX computer tied to DECnet you may access RADATA as follows:

1. Log-on your VAX computer.
2. Access the JPL computer by inputting SET HOST JPLLSI or SET HOST JPLUP.
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.
JPL/NASA RADIATION DATA BANK USERS SURVEY

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
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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.

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PREFACE

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

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

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

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


ACKNOWLEDGMENT

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

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

The sponsor of this publication is the NASA Office of Safety, Reliability, Maintainability and Hardness Assurance; NASA Headquarters, Code Q.
### 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/cm$^2$/second. The tests described here were irradiated at a given fluence level for exposure times between 5 and 45 minutes.

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

B. COBALT-60 SOURCES

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

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

A. GENERAL REMARKS

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

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

B. TRANSISTORS AND OPTICAL DEVICES

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

C. INTEGRATED CIRCUIT TESTING

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

A. BIPOLAR TRANSISTORS

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

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

For convenience, the degradation in transistor gain (h_FE) is plotted as Δ(1/h_FE) = 1/h_FE - 1/h_FE₀, where h_FE is the value at the specified radiation level, and h_FE₀ is the initial value. Implicit in this approach is the assumption that the radiation behavior can be approximated by the well-known formula:

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

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

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

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

2. Determine the minimum specified preirradiation h_FE for this device type. In this example, the initial specified minimum h_FE is 100. Then proceed as follows:

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

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

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

| $\Delta(1/h_{FE})$ | 10 | 12 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 70 | 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 | 48.9 | 53.3 | 58.1 | 62.9 | 67.2 | 72.5 | 76.0 | 81.3 | 86.2 | 90.9 | 93.5 | 102 | 111 | 122 | 132 | 139 | 156 | 162 | 182 | 222 | 263 | 294 | 323 |
| 0.0010 | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 48.9 | 53.3 | 58.1 | 62.9 | 67.2 | 72.5 | 76.0 | 81.3 | 86.2 | 90.9 | 93.5 | 102 | 111 | 122 | 132 | 139 | 156 | 162 | 182 | 222 | 263 | 294 | 323 |
| 0.0050 | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 48.9 | 53.3 | 58.1 | 62.9 | 67.2 | 72.5 | 76.0 | 81.3 | 86.2 | 90.9 | 93.5 | 102 | 111 | 122 | 132 | 139 | 156 | 162 | 182 | 222 | 263 | 294 | 323 |
| 0.0100 | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 48.9 | 53.3 | 58.1 | 62.9 | 67.2 | 72.5 | 76.0 | 81.3 | 86.2 | 90.9 | 93.5 | 102 | 111 | 122 | 132 | 139 | 156 | 162 | 182 | 222 | 263 | 294 | 323 |
| 0.0500 | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 48.9 | 53.3 | 58.1 | 62.9 | 67.2 | 72.5 | 76.0 | 81.3 | 86.2 | 90.9 | 93.5 | 102 | 111 | 122 | 132 | 139 | 156 | 162 | 182 | 222 | 263 | 294 | 323 |
| 0.1000 | 9.95 | 11.9 | 14.9 | 19.8 | 24.7 | 29.6 | 34.9 | 39.2 | 44.1 | 48.9 | 53.3 | 58.1 | 62.9 | 67.2 | 72.5 | 76.0 | 81.3 | 86.2 | 90.9 | 93.5 | 102 | 111 | 122 | 132 | 139 | 156 | 162 | 182 | 222 | 263 | 294 | 323 |

...
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: FSC  4 DEVICES TEST DATE 02-20-86
REF: JPL LOG 1246 DATE CODE 8352

\[\Delta(1/\text{h}_{\text{re}}) \text{ VS DOSE}\]

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![Graph showing dose response for different curves labeled A to F.]

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<th>Vce (V)</th>
<th>DOSE, rads(Si)</th>
<th>Δ(1/hFE) VS DOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.1000</td>
<td>20.0</td>
<td>7.5E4 1.5E3 3.0E3 6.0E3 1.0E6</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1.000</td>
<td>20.0</td>
<td>0.029 0.026 0.023 0.022 0.039</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.900</td>
<td>500.0</td>
<td>0.008 0.012 0.010 0.008 0.013</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1.000</td>
<td>20.0</td>
<td>0.011 0.007 0.006 0.004 0.010</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>20.00</td>
<td>20.0</td>
<td>0.003 0.002 0.002 0.002 0.003</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>20.00</td>
<td>500.0</td>
<td>0.003 0.002 0.002 0.002 0.003</td>
<td></td>
</tr>
</tbody>
</table>
DEVELOPMENT:

DEVICES TEST DATE 2-04-86

REF: JPL LOG 1228 DATE CODE 8530

TABLE OF NORMAL STANDARD DEVIATIONS

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<thead>
<tr>
<th>CURVE</th>
<th>Ic (mA)</th>
<th>Vcc (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>
<td>1.000</td>
<td>20.0</td>
<td>0.0026 0.0305 0.0158 0.0102 0.0126</td>
</tr>
<tr>
<td>B</td>
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<td>300</td>
<td>0.0026 0.0302 0.0153 0.0108 0.0104</td>
</tr>
<tr>
<td>C</td>
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<td>500</td>
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<td>20.0</td>
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<tr>
<td>F</td>
<td>20.00</td>
<td>500</td>
<td>0.0003 0.0023 0.0012 0.0008 0.0011</td>
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</tbody>
</table>
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: MOT
3 DEVICES
TEST DATE 2-04-86
REF: JPL LOG 1229
DATE CODE 8530

DOSE, rods(S:) 2.5 MeV electrons
$\Delta(1/h_{FE})$ VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>$I_c$ (mA)</th>
<th>$V_{cc}$ (V)</th>
<th>DOSE, rods(S:)</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>0.0015</td>
<td>0.0017</td>
<td>0.0022</td>
<td>0.0067</td>
<td>0.0023</td>
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<tr>
<td>B</td>
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<td>0.0014</td>
<td>0.0022</td>
<td>0.0029</td>
<td>0.0056</td>
<td>0.0029</td>
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</tr>
<tr>
<td>C</td>
<td>1.900</td>
<td>500</td>
<td>0.0006</td>
<td>0.0007</td>
<td>0.0008</td>
<td>0.0017</td>
<td>0.0009</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1.900</td>
<td>20.0</td>
<td>0.0005</td>
<td>0.0025</td>
<td>0.0009</td>
<td>0.0009</td>
<td>0.0007</td>
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</tr>
<tr>
<td>E</td>
<td>20.00</td>
<td>20.0</td>
<td>0.0004</td>
<td>0.0002</td>
<td>0.0003</td>
<td>0.0003</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>20.00</td>
<td>500</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0003</td>
<td>0.0003</td>
<td>0.0003</td>
<td></td>
</tr>
</tbody>
</table>
DEVICE TYPE: 2N2222A NPN TRANSISTOR
MFG: M4T 5 DEVICES TEST DATE 02-04-86
REF: JPL LOG 1230 DATE CODE 8530

![Graph showing the relationship between dose and the function \( \Delta(1/h_{eq}) \) for different curves labeled A to F.]

<table>
<thead>
<tr>
<th>CURVE</th>
<th>( I_c )</th>
<th>( V_{es} )</th>
<th>( \text{DOSE, rads(SI)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \mu A )</td>
<td>( V )</td>
<td>7.5E-4</td>
</tr>
<tr>
<td>A</td>
<td>1000</td>
<td>20.0</td>
<td>.0012</td>
</tr>
<tr>
<td>B</td>
<td>500</td>
<td>.500</td>
<td>.0013</td>
</tr>
<tr>
<td>C</td>
<td>1000</td>
<td>.500</td>
<td>.0006</td>
</tr>
<tr>
<td>D</td>
<td>20.00</td>
<td>20.0</td>
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<td>E</td>
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<td>.0002</td>
</tr>
<tr>
<td>F</td>
<td>.0000</td>
<td>.000</td>
<td>.0001</td>
</tr>
</tbody>
</table>

5-10
DOSE, rads(Si) 2.5 MeV electrons

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

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>I_c (mA)</th>
<th>V_ex (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>0.1000</td>
<td>20.0</td>
<td></td>
<td>0.0049</td>
<td>0.0062</td>
<td>0.0072</td>
<td>0.0062</td>
<td>0.0065</td>
</tr>
<tr>
<td>B</td>
<td>0.1000</td>
<td>500</td>
<td></td>
<td>0.0056</td>
<td>0.0091</td>
<td>0.0036</td>
<td>0.0066</td>
<td>0.0078</td>
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<tr>
<td>C</td>
<td>1.0000</td>
<td>500</td>
<td></td>
<td>0.0016</td>
<td>0.0039</td>
<td>0.0044</td>
<td>0.0020</td>
<td>0.0024</td>
</tr>
<tr>
<td>D</td>
<td>1.0000</td>
<td>20.0</td>
<td></td>
<td>0.0016</td>
<td>0.0029</td>
<td>0.0025</td>
<td>0.0025</td>
<td>0.0020</td>
</tr>
<tr>
<td>E</td>
<td>20.00</td>
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<td></td>
<td>0.0003</td>
<td>0.0002</td>
<td>0.0004</td>
<td>0.0008</td>
<td>0.0003</td>
</tr>
<tr>
<td>F</td>
<td>20.00</td>
<td>500</td>
<td></td>
<td>0.0003</td>
<td>0.0005</td>
<td>0.0006</td>
<td>0.0011</td>
<td>0.0006</td>
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</table>

5-11
Device Type: 2N3749 NPN Power Transistor
MFG: APC
3 Devices
Test Date 02-19-85
Ref: JPL Log 1211
Date Code 8510

Table of Normal Standard Deviations

<table>
<thead>
<tr>
<th>Curve</th>
<th>Ic</th>
<th>Vce</th>
<th>DOSE, rods(Si)</th>
<th>D(1/\eta fe)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[mA]</td>
<td>[V]</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1.000</td>
<td>3.00</td>
<td>.0402 .2381 .6168 1.062 1.034</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>10.00</td>
<td>3.00</td>
<td>.0110 .0429 .1044 .1250 .457</td>
<td></td>
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<tr>
<td>C</td>
<td>100.00</td>
<td>3.00</td>
<td>.0025 .0073 .0136 .0134 .0141</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1000.00</td>
<td>3.00</td>
<td>.0008 .0013 .0013 .0023 .0038</td>
<td></td>
</tr>
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5-12
DEVICE TYPE: 2N3749 NPN
MFG: PPC 3 DEVICES TEST DATE 01-08-86
REF: JPL LOG 1212 DATE CODE 8515

DE/VAC TYPE: 2tq3q49
NPN
P'_'G : PPC
RE,
C:
JPL LOG
"1232
DATE
CODE ,55t5

A(1/hfe) VS DOSE

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IC</th>
<th>VCE</th>
<th>DOSE, rads(Si) Co60 Gammas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mA</td>
<td>V</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5</td>
</tr>
<tr>
<td>A</td>
<td>1.00</td>
<td>5.00</td>
<td>.0016 .0036 .0040 .0045 .0045</td>
</tr>
<tr>
<td>B</td>
<td>5.00</td>
<td>5.00</td>
<td>.0022 .0028 .0028 .0027 .0031</td>
</tr>
<tr>
<td>C</td>
<td>5.00</td>
<td>5.00</td>
<td>.0003 .0003 .0005 .0003 .0005</td>
</tr>
<tr>
<td>D</td>
<td>1000</td>
<td>5.00</td>
<td>.0003 .0003 .0000 .0003 .0003</td>
</tr>
</tbody>
</table>
DEVICE TYPE: MJ16012 NPN POWER TRANSISTOR
MFG: MOTOR
5 DEVICES
TEST DATE 12-17-85
REF: JPL LOG 1220
DATE CODE NONE

DOSAGE, 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>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6</td>
</tr>
<tr>
<td>A</td>
<td>100.0</td>
<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>
<td>100.0</td>
<td>500.0</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>
<td>1000.0</td>
<td>500.0</td>
<td>0.0029 0.0062 0.0071 0.0093 0.0102 0.0121 0.0174</td>
</tr>
<tr>
<td>E</td>
<td>10000.0</td>
<td>50.0</td>
<td>0.0013 0.0019 0.0036 0.0041 0.0090 0.0068 0.0067</td>
</tr>
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DEVICE TYPE: MJ16012 NPN POWER TRANSISTOR

MFG: MOT 5 DEVICES TEST DATE 12-12-85

REF: JPL LOG 1221 DATE CODE NONE

TABLE OF NORMAL STANDARD DEVIATIONS

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<thead>
<tr>
<th>CURVE</th>
<th>I_C (mA)</th>
<th>V_CE (V)</th>
<th>DOSE, rads(Si)</th>
<th>Δ(1/ΔR_C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100.0</td>
<td>50.0</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6</td>
<td>0.0043 0.0074 0.0118 0.0136 0.0156 0.0173 0.0196</td>
</tr>
<tr>
<td>B</td>
<td>1000.0</td>
<td>500.0</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6</td>
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</tr>
<tr>
<td>C</td>
<td>1000.0</td>
<td>500.0</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6</td>
<td>0.0052 0.0085 0.0128 0.0145 0.0163 0.0181 0.0200</td>
</tr>
<tr>
<td>D</td>
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<td>500.0</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6</td>
<td>0.0258 0.0300 0.0344 0.0388 0.0433 0.0478 0.0523</td>
</tr>
<tr>
<td>E</td>
<td>10000.0</td>
<td>500.0</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6</td>
<td>0.0034 0.0068 0.0102 0.0137 0.0173 0.0209 0.0246</td>
</tr>
</tbody>
</table>
B. OPTICAL DEVICES

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

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

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

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

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

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

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

Failure Summary:

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

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

<table>
<thead>
<tr>
<th>Po @ krad(Si)</th>
<th>IF(mA)</th>
<th>PRE</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>2 hr</th>
<th>20 hr</th>
<th>100 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>390.0</td>
<td>256.3</td>
<td>176.3</td>
<td>63.8</td>
<td>108.8</td>
<td>218.8</td>
<td>260.0 mW</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>977.1</td>
<td>692.5</td>
<td>496.2</td>
<td>195.0</td>
<td>320.0</td>
<td>580.0</td>
<td>672.5 mW</td>
<td></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>
<td>1114.0 mW</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>2112.0</td>
<td>1629.0</td>
<td>1250.0</td>
<td>565.0</td>
<td>833.8</td>
<td>1366.0</td>
<td>1548.0 mW</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>2623.0</td>
<td>2623.0</td>
<td>1620.0</td>
<td>772.5</td>
<td>1097.0</td>
<td>1741.0</td>
<td>1954.0 mW</td>
<td></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>
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<td>IF = 40 mA</td>
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<td>FORWARD VOLTAGE</td>
<td>IF = 60 mA</td>
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<tr>
<td>4</td>
<td>VF-4</td>
<td>FORWARD VOLTAGE</td>
<td>IF = 80 mA</td>
</tr>
<tr>
<td>5</td>
<td>VF-5</td>
<td>FORWARD VOLTAGE</td>
<td>IF = 100 mA</td>
</tr>
<tr>
<td>6</td>
<td>Po-1</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 20 mA</td>
</tr>
<tr>
<td>7</td>
<td>Po-2</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 40 mA</td>
</tr>
<tr>
<td>8</td>
<td>Po-3</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 60 mA</td>
</tr>
<tr>
<td>9</td>
<td>Po-4</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 80 mA</td>
</tr>
<tr>
<td>10</td>
<td>Po-5</td>
<td>RELATIVE OUTPUT POWER</td>
<td>IF = 100 mA</td>
</tr>
</tbody>
</table>
Normalized Po [mW/cm^2] DATA -
4/27/87

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

- - Po @ IF = 20mA
- - Po @ IF = 40mA
- - Po @ IF = 60mA
- - Po @ IF = 80mA
- - Po @ IF = 100mA
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.
Table 1. I-LITE Versus Dose Level with Input Light Reference Current (IF) as a Parameter

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

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

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

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

The parameters measured were (RTR 412):

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Symbol</th>
<th>Test Name</th>
<th>Conditions (Reference source is a TIL24)</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 = 5 V, 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 = 5 V, 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 = 5 V, 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 = 5 V, 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 = 5 V, IF = 100 mA from reference source</td>
</tr>
<tr>
<td>8</td>
<td>VCE(SAT)</td>
<td>OUTPUT SATURATION VOLTAGE</td>
<td>IC = 0.4 mA, IF = 70 mA from reference source</td>
</tr>
</tbody>
</table>
NORMALIZED I-LITE DATA
4/27/87

LOG1258: Data TIX TIL604 NPN Planar Silicon Phototransistor

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

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

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: 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: (5) VOL 1-A (V)  (IOUT = 20 VA)
CURVE B: (6) VOL 1-B (V)  *
CURVE C: (7) VOL 2-A (V)  (IOUT = 24 MA)
CURVE D: (8) VOL 2-B (V)  *

DOSI, rads(Si) Co60 Gammas  TIME, hours
Device Type: 54AC74  Octal D-Type F/F
MFG: FSC  3 Devices  Test Date 2-11-87
REF: JPL LOG 1296  DATE CODE 8633

<table>
<thead>
<tr>
<th>CURVE A</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(9) I1H-A</td>
<td>(A) (VIN = VCC)</td>
<td></td>
</tr>
<tr>
<td>CURVE B</td>
<td>(10) I1H-B</td>
<td>(A) * *</td>
</tr>
<tr>
<td>CURVE C</td>
<td>(11) I1L-A</td>
<td>(A) (VIN = GND)</td>
</tr>
<tr>
<td>CURVE D</td>
<td>(12) I1L-B</td>
<td>(A) * *</td>
</tr>
</tbody>
</table>

PARAMETER MEAN VALUE

DOS, rad(Si) Co^{60} Gammas

TIME, hours

PRE-PAD

10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3}

EOR

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}

5-26
DEVICE TYPE: S4AC374 OCTAL D-TYPE FIF
MFG: FSC 3 DEVICES TEST DATE 2-11-67
REF: JPL LOG 1296 DATE CODE 8633

PARAMETERS | CONDITIONS
--- | ---
CURVE A: [13] 10ZH1-A (A) | (VIN = 3.66 V)
CURVE B: [14] 10ZH1-B (A) | *
CURVE C: [15] 10ZH2-A (A) | (VIN = 3.64 V)
CURVE D: [16] 10ZH2-B (A) | *

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

PRE-RAD

PARAMETER MEAN VALUE

\(10^{-6}\) \(10^{-7}\) \(10^{-8}\) \(10^{-9}\) \(10^{-10}\) \(10^{-11}\) \(10^{-12}\)
PARAMETERS

<table>
<thead>
<tr>
<th>Curve</th>
<th>Parameters</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I0ZL1-A (A)</td>
<td>(VIN = 3.66 V)</td>
</tr>
<tr>
<td>B</td>
<td>I0ZL1-B (A)</td>
<td>*</td>
</tr>
<tr>
<td>C</td>
<td>I0ZL2-A (A)</td>
<td>(VIN = 1.64 V)</td>
</tr>
<tr>
<td>D</td>
<td>I0ZLZ-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 6633

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IC</th>
<th>IC</th>
<th></th>
<th>PARAMETER</th>
<th>MEAN VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21</td>
<td>IC</td>
<td>A</td>
<td>ICH-A</td>
<td>10^5.5 ± 10^5.5</td>
</tr>
<tr>
<td>B</td>
<td>23</td>
<td>IC</td>
<td>A</td>
<td>ICCL-A</td>
<td>10^5.5 ± 10^5.5</td>
</tr>
<tr>
<td>C</td>
<td>25</td>
<td>IC</td>
<td>A</td>
<td>ICIZ-A</td>
<td>10^5.5 ± 10^5.5</td>
</tr>
</tbody>
</table>

DOSE, rads(S) Co^60 Gammas - EOR TIME, hours

PRE-RAD 10^5.5 1.5 2 3 4 6.6 10^5.5 1.5 2 3 4 6.6 10^5.5 2\n
PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IC</th>
<th>IC</th>
<th></th>
<th>PARAMETER</th>
<th>MEAN VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21</td>
<td>IC</td>
<td>A</td>
<td>ICH-A</td>
<td>10^5.5 ± 10^5.5</td>
</tr>
<tr>
<td>B</td>
<td>23</td>
<td>IC</td>
<td>A</td>
<td>ICCL-A</td>
<td>10^5.5 ± 10^5.5</td>
</tr>
<tr>
<td>C</td>
<td>25</td>
<td>IC</td>
<td>A</td>
<td>ICIZ-A</td>
<td>10^5.5 ± 10^5.5</td>
</tr>
</tbody>
</table>

5-29
DEVICE TYPE: 54AC374 OCTAL D-TYPE F1F
MFG: FSC  3 DEVICES TEST DATE 2-11-87
REF: JPL LOG 1296 DATE CODE 8633

PARAMETERS
CURVE A: (22) ICDH-B (A)
CURVE B: (24) ICDL-B (A)
CURVE C: (26) ICC2-B (A)

PARAMETER MEAN VALUE

DOSE, rads(Si) Co60 Gammas

TIME, hours

PRE-RAD 10^3 1.5 2. 3 4 5 6 10^4 3.5 2. 3 4 5 6 EOR

2.460-04 2.700-03 3.417-02 5.417-02 6.120-02 1.083-02 1.354-02 1.625-02 1.896-02 2.167-02

5-30
DEVICE TYPE: 54AC374 OCTAL D-TYPE FIF
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG J300 DATE CODE 8627

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURVE A</td>
<td>(1) VOH-A (V)</td>
</tr>
<tr>
<td>CURVE B</td>
<td>(2) VOH-B (V)</td>
</tr>
</tbody>
</table>

CONDITIONS

CONDITIONS

(IOUT = -20 UA)
DEVICE TYPE: 54AG374 JCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-67
REF: JPL LOG 1300 DATE CODE 8627

PARAMETERS
CURVE A: (3) V0112-A (V) CONDITIONS (IOUT = -5.2 MA)
CURVE B: (4) V0112-B (V)
PARAMETERS

CURVE A: (5) VOL1-A (V)
CURVE B: (6) VOL1-B (V)
CURVE C: (7) VOL2-A (V)
CURVE D: (8) VOL2-B (V)

CONDITIONS

(jout = 20 mA)
(jout = 5.2 mA)
PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(9) H+ A</td>
<td>(A) [VIN = VCC]</td>
</tr>
<tr>
<td>B</td>
<td>(10) H+ B</td>
<td>(A) *</td>
</tr>
<tr>
<td>C</td>
<td>(11) H- A</td>
<td>(A) [VIN = GND]</td>
</tr>
<tr>
<td>D</td>
<td>(12) H- B</td>
<td>(A) *</td>
</tr>
</tbody>
</table>
DEVICE TYPE: 54AC374 OCTAL D-TYPE F1/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1300 DATE CODE 6627

PARAMETERS CONDITIONS

CURVE A: (131) J07H3-A (A) (VIN = 4.2 V)
CURVE B: (14) J07H1-B (A) *
CURVE C: (15) J07H2-A (A) (VIN = 1.2 V)
CURVE D: (16) J07H2-B (A) *

DOSE, rads(Si) Co60 Gammas
TIME, hours

PARAMETER MEAN VALUE
DEVICE TYPE: 54AC374 OCTAL D-TYPE T/H
MFG: NSC 2 DEVICES TEST DATE 3-24-67
REF: JPL LOG 1300 DATE CODE 6627

PARAMETERS CONDITIONS
CURVE A: (17) 10ZL1-A (A) [VIN = 4.2 V]
CURVE E: (18) 10ZL1-B (A) [ ]
CURVE C: (20) 10ZL2-B (A) [VIN = 1.2 V]
DEVICE TYPE: 54AC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1300 DATE CODE 8627

PARAPERMEANVALUE

DOSE, rods(S); Caγ0 Gammns

PARAMETERS

CURVE A: (22) IC61+ B (A)
CURVE B: (24) IC61- B (A)
CURVE C: (26) IC62- B (A)
DEVICE TYPE: 54HC74 (DUAL D-TYPE R/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)

0.5 rads/sec Dose Rate
Dose, rads(Si) Co^60 Gammas
Time, hours
PRE-RAD 10^5 1.5 2. 3. 4. 5. 6. 10^4 1.5 2. 3. 4. 10^3 1.5 2. 3. 4. 5. 6. 10^2 4.6 10^1 4.6 10^2 4.6 10^3
DEVICE TYPE: 54HC74 (DUAL D-TYPE FF)
MFG: TIX  5 DEVICES TEST DATE 10-15-68
REF: JPL LOG 1374  DATE CODE 8801

PARAMETERS

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

CURVE A:  (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)
DEVICE TYPE: 54HC74 (DUAL D-TYPE F/F)
MFG: TIX 5 DEVICES TEST DATE 10-15-68
REF: JPL LOC 1374 DATE CODE 8801

PARAMETERS
CURVE A: (11) TPLHQ1 (S)
CURVE B: (12) TPHIQ1 (S)
CURVE C: (13) TPLHQ2 (S)
CURVE D: (14) TPHIQ2 (S)
DEVICE TYPE: 54HC374 CMOS OCTAL D-TYPE FF
MFG: NSC 3 DEVICES TEST DATE 11-13-63
REF: JPL L06 1215 DATE CODE R8520

Dose, rads(Si) Co60 Gammas

1) VOH (VCC=4.5V, JO=-6MA) IN V. 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>2.9E3 1.5E3 2.0E3 3.0E3 5.0E3 7.0E3 1.0E4 1.5E4 2.0E4 2.5E4 3.0E4</td>
<td>.0035 .0032 .0028 .0026 .0029 .0040 .0072 .0176 .0334 .0312 .0374</td>
</tr>
<tr>
<td>Dose</td>
<td>4.0E4</td>
<td>.0919</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOH(V) = 4.32X10^0
DEVICES TYPE: 54100374 CMOS OCTAL D-TYPE F1F

MTG: NSC  5 DEVICES  TEST DATE 11-13-65
DEF: JPL LUG 1215  DATE OJDE R6520

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

(2) VOL (VCC=4.5V, 10=6mA) IN MV: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>2.0E0 1.0E3 2.0E3 3.0E3 5.0E3 7.0E3 1.0E4 1.5E4 2.0E4 2.5E4 3.0E4</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>DOSE, rads(Si)</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></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>.0672 .0760 .0766 .0772 .0877 .1290 .2191 .5019 .9302 .8016 .9459</td>
<td></td>
</tr>
</tbody>
</table>

DOSER = 4.0E4
STD. DEV. = 2.063

INITIAL MEAN VALUE IOH(MA) = -6.63x10^2
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>DOSE</td>
<td>6.46</td>
<td>.1473</td>
</tr>
<tr>
<td></td>
<td>6.16</td>
<td>.1396</td>
</tr>
<tr>
<td></td>
<td>5.87</td>
<td>.1347</td>
</tr>
<tr>
<td></td>
<td>5.57</td>
<td>.1473</td>
</tr>
<tr>
<td></td>
<td>5.27</td>
<td>.1292</td>
</tr>
<tr>
<td></td>
<td>4.98</td>
<td>.2912</td>
</tr>
<tr>
<td></td>
<td>4.68</td>
<td>.4325</td>
</tr>
<tr>
<td></td>
<td>4.37</td>
<td>.5371</td>
</tr>
<tr>
<td></td>
<td>4.00</td>
<td>.7346</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOL(MA) = 6.64X10^10
DEVICE TYPE: 54HC374 CMOS OCTAL D-TYPE FF
MFG: NSC 5 DEVICES TEST DATE 11-13-85
REF: JPL LOG 1213 DATE CODE R6520

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

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0E0</td>
<td>1.0E3 2.0E3 3.0E3 5.0E3 7.0E3 1.0E4 1.5E4 2.0E4 2.5E4 3.0E4</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>.0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000 .0000</td>
<td></td>
</tr>
<tr>
<td>DOSE</td>
<td>4.0E4</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>126.9</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IIH(NA) = +9.99x10\textsuperscript{-1}

5-47
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>0.0E0</td>
<td>1.0E3</td>
<td>2.0E3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.1789</td>
</tr>
<tr>
<td></td>
<td>4.0E4</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IIL(NA) = 46.80X10⁻¹
DEVI0E TYPE: 54HC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 8627

PARAMETERS CONDITIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CURVE A:</td>
<td>1) VOH1-A</td>
<td>(V) (I_{OUT} = -20 UA)</td>
</tr>
<tr>
<td>CURVE B:</td>
<td>2) VOH1-B</td>
<td>(V) *</td>
</tr>
</tbody>
</table>
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

CURVE A: (3) $V_{OH2-A} (V)$
CURVE B: (4) $V_{OH2-B} (V)$

CONDITIONS

$\text{Dose, rads(Si): Co}^{60}$ Gammas

$\text{Pre-Rad} \quad 5 \times 10^4 \quad 6 \times 10^4 \quad 7 \times 10^4 \quad 8 \times 10^4 \quad 5 \times 10^5 \quad 6 \times 10^5 \quad 7 \times 10^5 \quad 8 \times 10^5 \quad \text{EOR}$

$\text{Time, hours}$

$5 \times 10^{-5} \quad 6 \times 10^{-5} \quad 7 \times 10^{-5} \quad 8 \times 10^{-5} \quad \text{EOR}$

$5.62 \quad 5.60 \quad 5.58 \quad 5.56 \quad 5.54 \quad 5.52 \quad 5.50 \quad 5.48 \quad 5.46 \quad 5.44 \quad 5.42$
DEVICE TYPE: 54HC374 OCTAL D-TYPE FF
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 6627

PARAMETERS CONDITIONS

<table>
<thead>
<tr>
<th>CURVE A:</th>
<th>PARAMETERS</th>
<th>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5) VOL1-A (V)</td>
<td>(IOUT = 20 UA)</td>
<td></td>
</tr>
<tr>
<td>CURVE B:</td>
<td>(6) VOL1-B (V)</td>
<td>&quot; &quot;</td>
</tr>
<tr>
<td>CURVE C:</td>
<td>(7) VOL2-A (V)</td>
<td>(IOUT = 5.2 MA)</td>
</tr>
<tr>
<td>CURVE D:</td>
<td>(8) VOL2-B (V)</td>
<td>&quot; &quot;</td>
</tr>
</tbody>
</table>
DEVICE TYPE: 54HC374  OCTAL D-TYPE F/F
MFG: NSC  3 DEVICES  TEST DATE 3-24-87
REF: JPL LOG 1301  DATE CODE 8627

PARAMETER MEAN VALUE

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

PRE-RAD  5  6  10$^4$  1.5  2  3  4  5  6  10$^5$  2  6 6.10$^2$  2

PARAMETERS  CONDITIONS

CURVE A:  (9) I1H-A  (A)  (VIN = VCC)
CURVE B:  (10) I1H-B  (A)  *  *
CURVE C:  (11) I1L-A  (A)  (VIN = GND)
CURVE D:  (12) I1L-B  (A)  *  *
DEVICE TYPE: 54HC374 OCTAL D-TYPE F/F
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 8627

PARAMETERS

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

DOSE, rad(Si) Co$^{60}$ Gammas

TIME, hours
PARAMETERS

CURVE A: (171) D0ZL1-A (A) (VIN = 4.2 V)
CURVE B: (161) D0ZL-B1 (A)
CURVE C: (191) D0ZL2-A (A) (VIN = 1.2 V)
CURVE D: (201) D0ZL2-B (A)
PARAMETERS

CURVE A: (21) ICCH-A (A)
CURVE B: (23) ICLL-A (A)
CURVE C: (25) ICCZ-A (A)
DEVICE TYPE: 54H0374 OCTAL D-TYPE FF
MFG: NSC 3 DEVICES TEST DATE 3-24-87
REF: JPL LOG 1301 DATE CODE 8627

PARAMETERS

CURVE A: (22) ICCH-B (A)
CURVE B: (23) ICCL-A (A)
CURVE C: (24) ICCL-B (A)
PARAMETERS

CURVE A: (1) IiH (VIH=15V) IN NA:
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AMD  2 DEVICES  TEST DATE 04-09-86
REF: JPL LOG 1250  DATE CODE 8531EMM

PARAMETERS

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

CURVE A: (3) IZS1 (INPUTS HIGH, J0 MEASURED) IN NA:
CURVE B: (4) IZS2 (INPUTS LOW, J0 MEASURED) IN NA:
DEVICE TYPE: AM6012N 12-BIT DAC
MFG: AMD    2 DEVICES    TEST DATE 04-09-86
REF: JPL L06 1250    DATE CODE 63316MN

PARAMETERS

CURVE A: 0.51 IFSS (IFS3-IFS4) IN NA:
DEVICE TYPE: AM6012A 12-BIT DAC
MFG: AMD 2 DEVICES TEST DATE 04-09-86
REF: JPL LOG 1250 DATE CODE 85316MM

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(Si) 2.5 MeV electrons
PARAMETERS

CURVE A: \( \text{(10) IREF (VREF=0V) IN NA} \)
DEVICE TYPE: AM6012A 12-BJT DAC
MFG: AMD  2 DEVICES  TEST DATE 04-09-86
REF: JPL L08 1250  DATE CODE 85313CH

PARAMETERS

CURVE A:  (13) NONLIN (MEAS'D DEV. 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:

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

Dose, rads(Si) 2.5 MeV electrons

Parameter Mean Value

PRE-RAD 10^4 10^5 10^6

A

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

PARAMETERS

CURVE A: 141 TPHL (MS2 50 POINT TO 10(-1) 50 POINT) IN NA:

---
DEVICE TYPE: CD4013 QUAD NAND GATE
MFG: RCA 3 DEVICES TEST DATE 09-13-86
REF: JPL LOG 1173 DATE CODE D407

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

CURVE A:  (3) VTN1=ON  (V)
CURVE B:  (4) VTN2=ON  (V)
CURVE C:  (7) VTN5=ON  (V)
CURVE D:  (6) VTN9=ON  (V)
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 3 DEVICES TEST DATE 09-15-66
REF: JPL LOG 1172 DATE CODE D407

PARAMETERS

- CURVE A: (5) VTN5 = OFF (V)
- CURVE B: (6) VTN6 = OFF (V)
- CURVE C: (9) VTN12 = OFF (V)
- CURVE D: (10) VTN13 = OFF (V)
DEVICE TYPE: CD4011 JUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-15-86
REF: JPL LOG 1173 DATE CODE D407

PARAMETERS

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

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

PARAMETER MEAN VALUE

PRE-RAD

10^2  1.5  3  4  5  6  8  10^3  2.5  3  4  5  6  10^4

EOR

10^2  4.6 10^3  4.6 10^4  4.6
PARAMETERS

CURVE A: (13) VTP5-ON (V)
CURVE B: (14) VTP6-ON (V)
CURVE C: (17) VTP12-ON (V)
CURVE D: (16) VTP13-ON (V)
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-15-66
REF: JPL LOG 1173 DATE CODE D407

PARAMETERS
CURVE A: \( (21) \) TPLH (NS)
CURVE B: \( (22) \) TAIL (NS)
DEVICE TYPE: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-86
REF: JPL LOG 1203 DATE CODE D407

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

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

PARAMETER MEAN VALUE

TIME, hours
EOR

10\textsuperscript{-1}

10\textsuperscript{0}

10\textsuperscript{1}

10\textsuperscript{2}

10\textsuperscript{3}

10\textsuperscript{4}

4.6 \times 10\textsuperscript{2}

4.6 \times 10\textsuperscript{3}

4.6 \times 10\textsuperscript{4}

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

DE-V
CD40 QU_IN_HI (TYP)

RE@: 0"Pl- I_06 _2C) D_ITE

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

Time, hours

Pre-Rad

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

Time, hours

PARAMETERS

CONDITIONS

CURVE A: (3) VTN 1-ON (V) (BIAS 15V)
CURVE B: (4) VTN 2-ON (V)
CURVE C: (5) VTN 3-ON (V)
CURVE D: (6) VTN 9-ON (V)
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: (3) 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) *
DEVI CE T Y P E: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-66
PFL: 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 5-OFF (V) \} \\
CURVE D: \{(16) VTP 9-OFF (V) \}
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>CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(13) VTP 5-ON (V) (V)</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>

5-77
DEVELOPMENT: CD4011 QUAD NAND GATE
MFG: RCA 5 DEVICES TEST DATE 09-17-66
REF: JPL LOG 1203 DATE CODE D407

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

PARAMETERS

CURVE A: (21) TPLH IN NS:
CURVE B: (22) TPHL IN NS:
DEVICE TYPE: CD4013 CMOS DUAL D F/F

MFG: SGS 5 DEVICES TEST DATE 06-22-83

REF: JPL LOC 1176 DATE CODE 352Y

**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>0.962 1.063 2.163 5.062 1.064 2.064 3.064 5.064 1.065</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>.0998 .2770 .2345 .2596 7.456 479.4 3272. 9417. XXXX</td>
</tr>
</tbody>
</table>

**Initial Mean Value IOH(UA)** = +2.13x10^3
DEVICE TYPE: CD4013 CMOS DUAL D F/F
MFG: SGS 3 DEVICES TEST DATE: 08-22-85
REF: JPL 106 1176 DATE CODE 352V

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

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

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE</th>
<th>rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>0.000</td>
<td>1.0E3</td>
</tr>
<tr>
<td></td>
<td>2.1E3</td>
<td>5.0E3</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>.0685</td>
<td>1.636</td>
</tr>
<tr>
<td></td>
<td>1.561</td>
<td>.2874</td>
</tr>
<tr>
<td></td>
<td>7.621</td>
<td>176.1</td>
</tr>
<tr>
<td></td>
<td>1102.</td>
<td>5267.</td>
</tr>
<tr>
<td></td>
<td>1572.</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOL(UA) = +1.25X10^8
DEVICE TYPE: CD4013 CMOS DUAL DFF
MFG: 868 3 DEVICES TEST DATE 06-22-65
REF: JPL LOG 1176 DATE CODE 352Y

Dose, rads(S.) Co60 Gammas

(3) VOL02 (10=6.6MA) VS V vs DOSE

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>0.0E0 1.0E3 2.0E3 3.0E3 4.0E3 5.0E3 6.0E3 7.0E3</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.046 0.0447 0.057 0.065 0.0447 0.057 0.2162 0.6544</td>
</tr>
</tbody>
</table>

Initial mean value VOL02(V) = +1.36x10^-5
DEVICE TYPE: CD4013 CMOS DUAL D FLIP-FLOP
MFG: S88 5 DEVICES TEST DATE 06-22-83
REF: JPL LOG 1176 DATE CODE 352V

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

\((4)\text{I\text{\textsuperscript{0}}H\text{\textsuperscript{0}}2} (\text{V}=13.5\text{V})\) IN \text{MA}: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(S.)</th>
<th>9.0E0</th>
<th>1.0E3</th>
<th>2.5E3</th>
<th>5.0E3</th>
<th>1.0E4</th>
<th>2.0E4</th>
<th>3.0E4</th>
<th>5.0E4</th>
<th>1.0E5</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>.3365</td>
<td>.3402</td>
<td>.3365</td>
<td>.3339</td>
<td>XXXX</td>
<td>.2763</td>
<td>.6789</td>
<td>1.729</td>
<td>XXXX</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE \(\text{I\text{\textsuperscript{0}}H\text{\textsuperscript{0}}2} \text{MA}) = -7.91\times10\text{\textsuperscript{-9}}
DEVICE TYPE: CD4013 CMOS DUAL D FF
MFG: SGS 3 DEVICES TEST DATE 06-22-85
REF: JPL LOG 1176 DATE CODE 352Y

DOSE, rads(Si) Co60 Gammas
(3) VOL02 (10*500A) IN MV: 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></td>
<td>0.9E0</td>
<td>2.9E7</td>
</tr>
<tr>
<td></td>
<td>1.0E3</td>
<td>5.9E10</td>
</tr>
<tr>
<td></td>
<td>2.1E3</td>
<td>1.0E4</td>
</tr>
<tr>
<td></td>
<td>5.0E3</td>
<td>2.0E4</td>
</tr>
<tr>
<td></td>
<td>1.0E4</td>
<td>3.0E4</td>
</tr>
<tr>
<td></td>
<td>2.0E4</td>
<td>5.0E4</td>
</tr>
<tr>
<td></td>
<td>1.0E5</td>
<td>2.0E5</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOL02(MV) = +1.67X10^3

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

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

(6) IOL02 (V0=1.5V) 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>0.0E0 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 .2327 .2450 .1717 .1769 .1460 .3657 .4016</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IOL02(MA) = +6.59\times10^{10}

* DEVICE PARAMETER FAILURE
DEVICE TYPE: QD4213 DUAL D FIF
MFG: SGS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1204 DATE CODE 352V

PARAMETERS
CURVE A: (510)ON(I\(\text{Na}\))
CURVE B: (2110)ON(I\(\text{Na}\))
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>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(3) VTN3-ON</td>
<td>(V)</td>
</tr>
<tr>
<td>B</td>
<td>(5) VTN5-ON</td>
<td>(V)</td>
</tr>
<tr>
<td>C</td>
<td>(6) VTN6-ON</td>
<td>(V)</td>
</tr>
<tr>
<td>D</td>
<td>(9) VTN10-ON</td>
<td>(V)</td>
</tr>
</tbody>
</table>

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

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>VTN4-Off (V)</th>
<th>VTN8-Off (V)</th>
<th>VTN9-Off (V)</th>
<th>VTN13-Off (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

DOSR, rads(Si) Co60 Gammas

TIME, hours

PRE-RAD

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

1.85

1.77

1.69

1.61

1.54

1.44

1.36

1.28

1.20
DEVICE TYPE: CD4013 DUAL D FF
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)
DEVICE TYPE: CD4013 DUAL D FF
MFG: SSB 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1267 DATE CODE 8321

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

* ACCELERATED ANNEAL
PARAMETERS

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

PARAMETERS

CURVE A: (4) VTN4-OFF (V)
CURVE B: (7) VTN8-OFF (V)
CURVE C: (8) VTN9-OFF (V)
CURVE D: (10) VTN11-OFF (V)
DEVCICE TYPE: CD4013 DUAL D FIF
MFG: SSS 5 DEVICES TEST DATE 10-29-86
REF: JPL Lg8 1267 DATE CODE 8321

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

PRE-RAD
DOSE, rads(Si) Co60 Gammas
EOR TIME, hours
PARAMETER MEAN VALUE
PARAMETERS
CURVE A: [23] TPLH4 (NS)
CURVE B: [24] TPLH42 (NS)
CURVE C: [25] TPLH43 (NS)
CURVE D: [26] TPLH42 (NS)
DEVICE TYPE: CD4013 DUAL D FF
MFG: SSS 5 DEVICES TEST DATE 10-29-86
REF: JPL LOG 1266 DATE CODE 8321

PARAMETERS

CURVE A: (191TFQ)(NS)
CURVE B: (201TFQ2)(NS)
CURVE C: (211TAQ)(NS)
CURVE D: (221TRAQ2)(NS)
PARAMETERS

CURVE A: (23) TPLH01 (NS)
CURVE B: (24) TPLH02 (NS)
CURVE C: (25) TPHLQ1 (NS)
CURVE D: (26) TPHLQ2 (NS)
DEVICE TYPE: HCF4007 INVERTER
MFG: 888 4 DEVICES TEST DATE 09-13-86
REF: JPL LOG 1378 DATE CODE 98822Y

PARAMETERS

CURVE A:  (1) IDS(N6)-ON (A)
CURVE B:  (2) IDS(N6)-OFF (A)
CURVE C:  (3) IDS(N10)-ON (A)
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS  4 DEVICES  TEST DATE 09-13-86
REF: JPL L08 1376  DATE CODE 96622Y

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

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

PARAMETER MEAN VALUE

DOSE  
10^3  1.5  2  2.5  3  3.5  4  4.5  5  6  7  8  9  10^4

PRE-
RAD  

2.600-10
2.597-10
2.594-10
2.191-10
1.987-10
1.784-10
1.476-10
1.175-10

5-102
PARAMETERS

CURVE A: [7] VTN(6)-ON (V1)
CURVE B: [6] VTN(3)-OFF (V1)
CURVE C: [9] VTP(10)-ON (V1)

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

PARAMETER MEAN VALUE

DEVI CE TYPE: HCF4007 INVERTER
MFG: 888 4 DEVICES TEST DATE 09-13-88
REF: JPL LOG 1378 DATE CODE 98822Y

TRE: JPL LOG 1378 DEVICES ES
DR_E 09-13-00

B - PRE-10 3
CURVE A:
CURVE B:
CURVE C:
DEVICE TYPE: HCF4007 INVEPTER
MFG: SBS 4 DEVICES TEST DATE 09-13-86
REF: JPL LOG 1316 DATE CODE 96822Y

PARAMETERS

CURVE A: \(\text{VTP(6)}\)-OFF (V)
CURVE B: \(\text{VTP(3)}\)-ON (V)
CURVE C: \(\text{VTP(10)}\)-OFF (V)

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

PRE-RAD 10\textsuperscript{3} 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 10\textsuperscript{4}

PARAMETER MEAN VALUE

-1.72 -1.64 -1.56 -1.48 -1.40 -1.32 -1.24 -1.16 -1.08 -1.00 -0.92 -0.84

5-104
PARAMETERS

CURVE A: (1) IDS(N)-ON (A)
CURVE B: (2) IDS(N)-OFF (A)
CURVE C: (3) IDS(N01)-ON (A)

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

0.5 rads/sec Dose Rate

PARAMETERS

CURVE A: (1) IDS(N)-ON (A)
CURVE B: (2) IDS(N)-OFF (A)
CURVE C: (3) IDS(N01)-ON (A)
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 09-15-86
REF: JPL LOG 1379 DATE CODE 96622Y

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

DOSE, rads(Si) Co\textsuperscript{60} Gammas
0.5 rads/sec Dose Rate
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\textsuperscript{60} Gammas
0.5 rads/sec Dose Rate
DEVICE TYPE: HCF4097 INVERTER
MFG: 58S 4 DEVICES TEST DATE 09-15-88
REF: JPL LOG 1379 DATE CODE 96622V

DOSE, rads(Si) Co<sup>60</sup> Gammas
0.5 rads/sec Dose Rate

PARAMETERS
CURVE A: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF (V)
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 09-19-88
REF: JPL L08 1360 DATE CODE 96822Y

PARAMETERS

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

Dose, rads(S) Co60 Gamma
DEVICE TYPE: HCF4007 INVERTER
MFB: 888 4 DEVICES TEST DATE 09-19-86
REF: JPL 108 1380 DATE CODE 98822Y

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IDSP</th>
<th>Value</th>
<th>(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
<td>OFF</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>ON</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>OFF</td>
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DEVICE TYPE: HCF4007 INVERTER

MFG: SGS 4 DEVICES TEST DATE 09-19-86

REF: JPL L08 1360 DATE CODE 98822Y

PARAMETERS

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<th>VALUE</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>A</td>
<td>7.7</td>
<td>VTN(6)-ON (V)</td>
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<tr>
<td>B</td>
<td>8.3</td>
<td>VTN(2)-OFF (V)</td>
</tr>
<tr>
<td>C</td>
<td>9.0</td>
<td>VTP(10)-ON (V)</td>
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PARAMETERS

CURVE A:  \((10) \text{ VTP}(6) - \text{OFF} (V)\)
CURVE B:  \((11) \text{ VTP}(3) - \text{ON} (V)\)
CURVE C:  \((12) \text{ VTP}(10) - \text{OFF} (V)\)
Do not hallucinate.
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 09-19-86
REF: JPL L05 1366 DATE CODE 98822Y

PARAMETERS
CURVE A: (4) IDSP(6)-OFF (A)
CURVE B: (5) IDSP(3)-ON (A)
CURVE C: (6) IDSP(30)-OFF (A)
DEVICE TYPE: HCF4007 INVERTER
MFG: SBS 4 DEVICES TEST DATE 09-19-88
REF: JPL LOG 1368 DATE CODE 96622Y

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
20 rads/sec Dose Rate

PRE-RAD $10^3$

PARAMETER MEAN VALUE
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 09-19-88
REF: JPL LOG 1366 DATE CODE 98822Y

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

PARAMETERS
CURVE A: (10) VTP(6)--OFF (V)
CURVE B: (11) VTP(3)--ON (V)
CURVE C: (12) VTP(10)--OFF (V)
DEVICE TYPE: 40F4007 INVERTER
MFG: 968 4 DEVICES TEST DATE 10-03-86
REF: JPL L08 1369 DATE CODE 98822Y

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

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Parameter Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>IDS\textsuperscript{6}ON</td>
<td>(A)</td>
</tr>
<tr>
<td>B</td>
<td>IDS\textsuperscript{3}OFF</td>
<td>(A)</td>
</tr>
<tr>
<td>C</td>
<td>IDS\textsuperscript{10}ON</td>
<td>(A)</td>
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</table>
DEVICE TYPE: HCF4007 INVERTER
MFG: SGS 4 DEVICES TEST DATE 10-03-86
REF: JPL LOB 1389 DATE CODE 98622Y

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

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: SGS 4 DEVICES TEST DATE 10-03-88

REF: JPL 108 1389 DATE CODE 98822Y

PARAMETERS

CURVE A: (7) VTN(5)-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 10-03-88
REF: JPL LOG 1389 DATE CODE 98622Y

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

PARAMETERS
CURVE A: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF (V)
DEVICE TYPE: HCF4007 INVERTER
MFG: 988 4 DEVICES TEST DATE 10-10-88
REF: JPL LOS 1390 DATE CODE 98622Y

PARAMETER MEAN VALUE

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

PARAMETERS
CURVE A: (1) IDS\textsuperscript{N}(6)-ON (A)
CURVE B: (2) IDS\textsuperscript{N}(3)-OFF (A)
CURVE C: (3) IDS\textsuperscript{N}(10)-ON (A)

5-121
DEVICE TYPE: HCF4007 INVERTER
MFG: 588       4 DEVICES    TEST DATE 10-10-88
REF: JPL LOG 1390       DATE CODE 96622Y

DOSE, rads(Si) Co^{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: HCF4007 INVERTER
MFG: SGS  4 DEVICES  TEST DATE 10-10-88
REF: JPL LOG 1390  DATE CODE 98822Y

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

PARAMETERS

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

5-123
DEVICE TYPE: HCF4007 INVERTER

MFG: SBS  4 DEVICES  TEST DATE 10-10-88
REF: JPL 108 1390  DATE CODE 98622Y

PARAMETERS

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

DOSE, rads(Si) Co\textsuperscript{60} Gammas
0.0058 rads/sec Dose Rate
DEVICE TYPE: HGF4013  DUAL D-TYPE F/1F
MFG: SGS  6 DEVICES  TEST DATE 07-19-66
REF: JPL LJD 1360  DATE CODE 98814Y

PARAMETERS

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

1.0 rads/sec Dose Rate
PARAMETERS

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)

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

1.0 rads/sec Dose Rate
DEVICE TYPE: HOF4013 DUAL D-TYPE F/F
MFG: SGS 6 DEVICES TEST DATE 07-19-86
REF: TPL LOG 1360 DATE CODE 98834Y

PARAMETERS

CURVE A: (19) TPLHQ1 (S)
CURVE B: (20) TPLHQ1 (S)
CURVE C: (21) TPLH02 (S)
CURVE D: (22) TPHLO2 (S)

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

TIME, hours

PARAMETER MEAN VALUE

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

PARAMETERS

CURVE A: (19) TPLHQ1 (S)
CURVE B: (20) TPLHQ1 (S)
CURVE C: (21) TPLH02 (S)
CURVE D: (22) TPHLO2 (S)

5-128
DEVICE TYPE: HCF4013 DUAL D-TYPE FIT
MFG: SGS 6 DEVICES TEST DATE 06-06-88
REF: JPL LOG 1364 DATE CODE 96814Y

PARAMETER MEAN VALUE

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

PARAMETERS

CURVE A:  (1) 10H  (A)
CURVE B:  (2) 10L  (A)
DEVICE TYPE: HOF4013  DUAL D-TYPE F1/F
MFG: SGS  6 DEVICES  TEST DATE 08-08-88
REF: JPL LOG 1364  DATE CODE 96814Y

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)

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

TIME, hours

PRE-RAD

10\textsuperscript{-3}  1.5  2  3  4  5  6  7  8  9  10

1.45

1.06

0.66

0.27

-0.12

-0.31

-0.91

-1.30
PARAMETERS

CURVE A: (1) IQH(NA)
CURVE B: (2) IQL(NA)
DEVICE TYPE: HC4038E DUAL D FIF
MTBF: 968 5 DEVICES TEST DATE 9-25-66
P/N: JFL 018 1177 DATE CODE 352Y

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>PARAMETER</th>
<th>SYMBOL</th>
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<tbody>
<tr>
<td>A</td>
<td>VTNC-ON</td>
<td>(3)</td>
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<tr>
<td>B</td>
<td>VTNS-ON</td>
<td>(5)</td>
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<tr>
<td>C</td>
<td>VTNK-ON</td>
<td>(6)</td>
</tr>
<tr>
<td>D</td>
<td>VTNS-ON</td>
<td>(9)</td>
</tr>
</tbody>
</table>

DOSAGE (S) Co^{60} Gamma

PPE-PAD

2.22

2.01

1.79

1.56

1.52

1.50

1.48

1.46

1.44

1.42

1.40

1.38

1.36

1.34

1.32

1.30

1.28

1.26

1.24

1.22

1.20

1.18

1.16

1.14

1.12

1.10

1.08

1.06

1.04

1.02

1.00

0.98

0.96

0.94

0.92

0.90

0.88

0.86

0.84

0.82

0.80

0.78

0.76

0.74

0.72

0.70

0.68

0.66

0.64

0.62

0.60

0.58

0.56

0.54

0.52

0.50

0.48

0.46

0.44

0.42

0.40

0.38

0.36

0.34

0.32

0.30

0.28

0.26

0.24

0.22

0.20

0.18

0.16

0.14

0.12

0.10

0.08

0.06

0.04

0.02

5-132
DEVICE TYPE: HCF4013BE DUAL D F/F
MFG: SGS 5 DEVICES TEST DATE 9-25-86
PER: JPL LAB 1177 DATE CODE 352V

PARAMETERS

| CURVE A:  | VTN4-OFF (V) |
| CURVE B:  | VTN8-OFF (V) |
| CURVE C:  | VTN9-OFF (V) |
| CURVE D:  | VTN12-OFF (V) |

DOSI, rads (Si) Ca60 Gammas
DEVICE TYPE: 4013BE DUAL D F/F
MFG: SGS 5 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1177 DATE CODE 372Y

PARAMETER MEAN VALUE

DOSE, rads(Si) Co^60 Gammas

PARAMETERS
CURVE A: (19)TF1(NS)
CURVE B: (20)TF2(NS)
CURVE C: (21)TR1(NS)
CURVE D: (22)TR2(NS)

5-136
PARAMETERS

CURVE A: (23) TPLH1 (NS)
CURVE B: (24) TPLH2 (NS)
CURVE C: (25) TPLH1 (NS)
CURVE D: (26) TPLH2 (NS)
DEVICE TYPE: HCF4013BE DUAL D/F/F
MFG: 568 5 DEVICES  TEST DATE 9-23-66
REF: JPL LOG 1178  DATE CODE 332Y

PARAMETERS

CURVE A: (1)IQ1(NA)
CURVE B: (2)IQ1(NA)
DEVICE TYPE: HCF4013BE 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)
DEVICE TYPE: 4CF4013BE DUAL D F/F
MFG: SGS 3 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1176 DATE CODE 352Y

PARAMETERS

CURVE A: (4) VTN4-OFF (V)
CURVE B: (7) VTN5-OFF (V)
CURVE C: (8) VTN9-OFF (V)
CURVE D: (10) VTN11-OFF (V)
DEVICE TYPE: HCF4013BE DUAL D F/F
MFG: S8S 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)
DEVICE TYPE: HCF4013BE DUAL D'F/F
MFG: SB5 3 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1178 DATE CODE 352Y

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

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

PARAMETER MEAN VALUE

PRE- RAD $10^2$ 1.5 2. 3. 4. 5. 6. 6. $10^2$ 1.5 2. 3. 4. 5. 6.
DEVI CE TYPE: HC4013BE DUAL D FIF
MFG: 88S 3 DEVICES TEST DATE 9-25-86
REF: JPL L06 1176 DATE CODE 352Y

![Graph Image]

PARAMETERS

CURVE A: 191TF1(NS)
CURVE B: 120TF2(NS)
CURVE C: 21TR1(NS)
CURVE D: 22TR2(NS)
DEVICE TYPE: HG4013BE DUAL D FIT
MFG: SGS 7 DEVICES TEST DATE 9-25-86
REF: JPL LOG 1176 DATE CODE 352Y

PARAMETERS
CURVE A: (23)TPL1(NS)
CURVE B: (24)TPL2(NS)
CURVE C: (25)TPH1(NS)
CURVE D: (26)TPH2(NS)
DEVICE TYPE: LF356BH FET INPUT OP AMP
MFG: NSC 3 DEVICES TEST DATE 12-06-85
REF: JPL L08 1168 DATE CODE HE448

DOSE, rads(Si) Co$^{60}$ Gammas
(1) VOS (RS=30 OHMS) IN MV: VS DOSE

<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>1.200 1.237 1.220 1.166 0.9332 1.011 .6604 1.777 3.646 13.69</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOS(MV) = -6.63X10^{-3}
DEVICE TYPE: LF356BH FET INPUT OP AMP
MFB: NSC 3 DEVICES TEST DATE 12-06-83
REF: JPL LSB 1168 DATE CODE H8448

DOSE, rads(Si) Co60 Gammas
(2) JOS (VOUT=OV) IN NA: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.9E0 1.0E4 2.0E4 3.0E4 5.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6</td>
<td>0.0007 .0006 .0042 .0145 .0165 .0943 16.67 310.7 116.6 31.90</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE JOS(INA) = +3.79X10^-6
DEVICE TYPE: LF336BH FET INPUT OP AMP
MFG: NSC 3 DEVICES TEST DATE 12-06-85
REF: JPL LOG 1168 DATE CODE H6448

DOSE, rads(Si) Co60 Gammas
(3) IB (VOUT=OV) IN NA VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0X0 1.0X4 2.0X4 3.0X4 5.0X4 7.5X4 1.5X5 3.0X5 6.0X5 1.0X6</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>.0025 .0033 .0165 .0230 .0733 .1666 15.91 151.1 53.10 14.10</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IB(INA) = 47.61X10^-2
DOSE, \( \text{rads(Si)} \) Ca\(^{60} \) Gammas

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

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, ( \text{rads(Si)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>( 0.9 \times 10^4 )</td>
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<tr>
<td>Std. Dev.</td>
<td>2.495</td>
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</table>

INITIAL MEAN VALUE GAIN(DB) = \( +1.35 \times 10^{-2} \)
TABLE OF NORMAL STANDARD DEVIATIONS

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<thead>
<tr>
<th>DOSE</th>
<th>STD. DEV.</th>
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<tbody>
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</tr>
<tr>
<td>1.0E4</td>
<td>2.261</td>
</tr>
<tr>
<td>2.0E4</td>
<td>2.517</td>
</tr>
<tr>
<td>3.0E4</td>
<td>2.232</td>
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<td>5.0E4</td>
<td>1.624</td>
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<tr>
<td>7.5E4</td>
<td>2.116</td>
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<td>1.5E5</td>
<td>2.396</td>
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<tr>
<td>3.0E5</td>
<td>16.33</td>
</tr>
<tr>
<td>6.0E5</td>
<td>24.37</td>
</tr>
<tr>
<td>1.0E6</td>
<td>17.06</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE - GAIN(DB) = 41.33x10²

DOSE, rads(Si) Co⁶⁰ Gammas

GRAPH - GAIN (VOUT=1.0V) IN DB vs DOSE

DEVICE TYPE: LF356BH FET INPUT OP AMP

MFG: NSC 3 DEVICES TEST DATE 12-06-85

REF: JPL LOG 1166 DATE CODE HE448
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0E4 2.0E4 3.0E4 5.0E4 7.5E4</td>
</tr>
<tr>
<td>A</td>
<td>0.165 0.3407 0.911 1.209 1.969</td>
</tr>
</tbody>
</table>
DEVICE TYPE: LF356BH OP AMP
MFG: NSC 4 DEVICES  TEST DATE 09-30-85
REF: JPL LOG 1169  DATE CODE H844B

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

(2) (Dose(NA)) vs DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0E4</td>
<td>2.0E4 3.0E4 5.0E4 7.5E4</td>
</tr>
<tr>
<td>5</td>
<td>.1134 .1526 .0844 .0776 .0911</td>
</tr>
</tbody>
</table>

TABLE OF NORMAL STANDARD DEVIATIONS
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>Mean</th>
<th>SD(Na)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.0E4 2.0E4 3.0E4 5.0E4 7.5E4</td>
<td>.2459 .2254 .2654 .3876 .4585</td>
<td></td>
</tr>
</tbody>
</table>

DEVICE TYPE: LF356EH UP AMP
MFG: NSC 4 DEVICES TEST DATE 09-30-85
REF: JPL LOG 1169 DATE CODE HF44E
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>$I_L$</th>
<th>DOSE, rads(Si)</th>
<th>$\mu$Gans</th>
<th>$\mu$Gans</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I$</td>
<td>1.76E4 2.04E4 3.04E4 5.04E4 7.5E4</td>
<td>1.00E3 2.76E3 3.7E3 2.29E2 2.97E2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$D$</td>
<td>1.76E3 2.76E3 3.7E3 2.29E2 2.97E2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE $+\text{GAIN(DB)} = 1.5 \times 10^2$
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Dose [rad(Si)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1.0E4 2.0E4 3.0E4 5.0E4 7.5E4</td>
</tr>
<tr>
<td>L</td>
<td>1.00 4.0E4 3.6E4 3.2E4 3.27 3.162</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE -GAIN(DB) = 1.2X10^4
DEVICE TYPE: LT1012 OP AMP
MFG: LTC 4 DEVICES TEST DATE 12-16-65
REF: JPL LOG 1150 DATE CODE 6437

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

(1)VOS (R8=50 OHMS) IN MV: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.0DE4 1.0E4 2.0E4 3.0E4 5.0E4</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>.0242 .0261 .2639 .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

DOSE, rads(Si) Co$^{60}$ Gamma

(2)$10^8$/VOUT=0V) IN PA: VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0E0</td>
<td>1.0E4 2.0E4 3.0E4 5.0E4</td>
<td>51.07 66.58 93.39 258.6 9757.</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE IO(S,PA) = -1.69X10$^{11}$
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
(4)+GAIN (VOUT=10V,PL=2XOHMS) IN DB VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
<th>GAIN (DB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE</td>
<td>0.0E0 1.0E4 2.0E4 3.0E4 5.0E4</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>3.261 11.06 12.06 1.160 2.466</td>
<td></td>
</tr>
</tbody>
</table>

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

5-158
DEVI CE TYPE: LT1012 Op Amp
MFG: LTC  4 DEVICES TEST DATE 12-16-85
REF: JPL LUB 1150  DATE CODE 6437

\[ \text{DOSE, rads(S;)} \text{ Co}^{60} \text{ Gam mas} \]

\[ (5)\text{-GAIN (VOUT=-10V, PL=2K OHMS) IN D VS DOSE} \]

<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 5.0E4</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>1.738 2.322 7.476 .7661 .7135</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE (GAIN(DB)) = +5.45X10^4

5-159
PARAMETERS

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

PARAMETER MEAN VALUE

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

TIME, hours

PRE-RAD

EOR

PARAMETERS

CURVE A: 14 IDSP(6)-OFF (A)
CURVE B: 15 IDSP(3)-ON (A)
CURVE C: 16 IDSP(10)-OFF (A)
DEVICE TYPE: MC14007 D COMPLIMENTARY W/INVER
MFG: MOT 6 DEVICES TEST DATE 09-07-86
REF: JPL LOG 1376 DATE CODE FR 8705

PARAMETERS

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

PARAMETERS

CURVE A: (7) VTN(6)-ON (V)
CURVE B: (8) VTN(3)-OFF (V)
CURVE C: (9) VTP(10)-ON (V)
DEVICE TYPE: 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: (10) VTP(6)-OFF (V)
CURVE B: (11) VTP(3)-ON (V)
CURVE C: (12) VTP(10)-OFF (V)

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

PARAMETER MEAN VALUE

PRE-RAD 10^3 1.5 2 3 4 5 6 10^4 1.5 2 10^2 4.4010^2 4.410^2 4.410^3
DEVICE TYPE: MC14007 D COMPLIMENTARY WITHIN
MFG: MOT 6 DEVICES TEST DATE 06-17-86
REF: JPL LOG 1377 DATE CODE FR 8705

PARAMETERS

CURVE A: 1) IDSN(6)-ON (A)
CURVE B: 2) IDSN(3)-OFF (A)
CURVE C: 3) IDSN(10)-ON (A)
DEVICE TYPE: MC14007 D COMPLIMENTARY W/INVER
MFG: MCT 6 DEVICES TEST DATE 06-17-85
REF: JPL LOG 1377 DATE CODE FR 8705

20 rads/sec Dose Rate

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 WINVER
MFG: MOT 6 DEVICES TEST DATE 06-17-88
REF: JPL LOG 1377 DATE CODE FR 8705

PARAMETERS

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

PARAMETERS

CURVE A: (10) VTP(6)-ON (V1)
CURVE B: (11) VTP(3)-OFF (V1)
CURVE C: (12) VTP(10)-OFF(V1)

DOSE, rads(Si) Cs^60 Gammas
20 rads/sec Dose Rate

TIME, hours

PARAMETER MEAN VALUE

PRE-RAD

EOR

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

-2.04  -1.90  -1.77  -1.63  -1.50  -1.37  -1.23  -1.10  -0.97
DOSE, rads(Si) Co\textsuperscript{60} Gammas
0.0156 rads/sec Dose Rate

PARAMETERS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>IDSN</th>
<th>STATUS</th>
<th>PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(1)</td>
<td>IDSN(6)--ON</td>
<td>(A)</td>
</tr>
<tr>
<td>B</td>
<td>(2)</td>
<td>IDSN(3)--OFF</td>
<td>(A)</td>
</tr>
<tr>
<td>C</td>
<td>(3)</td>
<td>IDSN(10)--ON</td>
<td>(A)</td>
</tr>
</tbody>
</table>

5-168
DEVICE TYPE: MC14007 CMOS INVERTER
MFG: MCT  3 DEVICES  TEST DATE 10-10-88
REF: JPL LOG 1392  DATE CODE FF 87361

DOSE, rads(Si) Co60 Gammas
0.0156 rads/sec Dose Rate

PARAMETERS

CURVE A:  [4] IDSP(6)-ON  (A)
CURVE B:  [5] IDSP(3)-OFF  (A)
CURVE C:  [6] IDSP(10)-OFF  (A)
DEVICE TYPE: MC14027 CMOS INVERTER
MFG: MOT 5 DEVICES TEST DATE 10-10-88
REF: JPL LOG 1392 DATE CODE FF 87361

DOSE, rads(Si) Co\textsuperscript{60} Gammas
0.0156 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: MC14007 CMOS INVERTER
MFG: MCT 5 DEVICES TEST DATE 10-10-88
REF: JPL L08 1392 DATE CODE FF 6736

DOSE, rads(SI) Co^{60} Gammans
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)
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.9E4 7.9E4 1.5E5 3.9E5 6.9E5 1.0E6 2.0E6 1.0E0 3.0E0 8.0E0 2.4E1</td>
<td>2.925 1.574 1.124 2.126 3.673 6.128 12.33 12.07 12.58 12.51 12.67</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2E1 2.4E2 7.2E2 2.4E3</td>
<td>16.45 13.96 13.13 13.75</td>
</tr>
</tbody>
</table>
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads (S.)</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
<td>1.5E5</td>
</tr>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
<td>6.0E5</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>9.345</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>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads (S.)</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2E1</td>
<td>2.4E2</td>
<td>7.2E2</td>
</tr>
<tr>
<td>2.4E3</td>
<td></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>
DEVICE TYPE: UP-27 OP AMP
MFG: SUB 5 DEVICES TEST DATE 05-15-86
REF: JPL LOG 1162 DATE CODE 8503

(4) +GAIN (1K LOAD=10MA, +10V) IN DBB VS DOSE

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rods(Si) Co60 Gammas</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
<td>1.5E5</td>
</tr>
<tr>
<td>1.5E5</td>
<td>3.0E5</td>
<td>6.0E5</td>
</tr>
<tr>
<td>6.0E5</td>
<td>1.0E6</td>
<td>2.0E6</td>
</tr>
<tr>
<td>1.0E6</td>
<td>2.0E6</td>
<td>1.0E0</td>
</tr>
<tr>
<td>2.0E6</td>
<td>3.0E6</td>
<td>8.0E0</td>
</tr>
<tr>
<td>1.0E0</td>
<td>2.4E1</td>
<td>2.296</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>2.7512</td>
</tr>
<tr>
<td>1.5E5</td>
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<tr>
<td>6.0E5</td>
<td>3.192</td>
</tr>
<tr>
<td>1.0E6</td>
<td>3.265</td>
</tr>
<tr>
<td>2.0E6</td>
<td>3.069</td>
</tr>
<tr>
<td>1.0E0</td>
<td>2.369</td>
</tr>
<tr>
<td>2.4E1</td>
<td>2.662</td>
</tr>
<tr>
<td>2.296</td>
<td>2.514</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>3.0E4</th>
<th>7.5E4</th>
<th>1.5E5</th>
<th>3.0E5</th>
<th>6.0E5</th>
<th>1.2E6</th>
<th>2.0E6</th>
<th>1.0E7</th>
<th>3.0E7</th>
<th>6.0E7</th>
<th>1.0E8</th>
<th>2.4E8</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>.5870</td>
<td>1.031</td>
<td>1.051</td>
<td>.5115</td>
<td>.7417</td>
<td>1.038</td>
<td>1.179</td>
<td>1.179</td>
<td>1.036</td>
<td>.7614</td>
<td>.7916</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE -GAIN(DB) = +1.23X10^2
### Table of Normal Standard Deviations

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>3.0E-4</th>
<th>7.5E-5</th>
<th>1.5E-5</th>
<th>3.0E-5</th>
<th>1.0E0</th>
<th>4.6E-1</th>
<th>7.2E-1</th>
<th>2.4E2</th>
<th>7.2E2</th>
<th>2.4E3</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>1539</td>
<td>0.0736</td>
<td>0.2284</td>
<td>5.677</td>
<td>3.768</td>
<td>1.660</td>
<td>1.389</td>
<td>0.911</td>
<td>0.0457</td>
<td>0.0314</td>
</tr>
</tbody>
</table>

(1) \( \Delta V_{OS} \) in MV vs Dose

**Figure Description:**
- **Device Type:** UP-27 OP AMP
- **Manufacturer:** LTC
- **Device Count:** 5
- **Test Date:** 05-15-66
- **Reference:** JPL Log 1142
- **Date Code:** 6576

**Graph:**
- **X-axis:** DOSE, rads(S) Co\(^{60}\) Comas
- **Y-axis:** \( \Delta V_{OS}, \) X10\(^{-4} \) MV
- **Legend:** (A)
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</td>
<td>1.5E5 3.0E5</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>19.49 21.19 104.9</td>
</tr>
</tbody>
</table>

* MEASUREMENT PROBLEM
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></td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 1.0E6 4.6E6 7.2E6 2.4E7 7.2E7 2.4E8 7.2E8 2.4E9</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>39.36 146.1 20.01 132.5 128.6 76.11 109.6 123.5 104.5 91.44</td>
<td></td>
</tr>
</tbody>
</table>
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 DDB VS DOSE

<table>
<thead>
<tr>
<th>DOSE, rads(Si)</th>
<th>CO₂ Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>7.5E4</td>
</tr>
<tr>
<td>1.5E4</td>
<td>1.5E4</td>
</tr>
<tr>
<td>3.0E5</td>
<td>1.0E0</td>
</tr>
<tr>
<td>4.6E6</td>
<td>7.2e1</td>
</tr>
<tr>
<td>2.4E2</td>
<td>7.2E2</td>
</tr>
<tr>
<td>2.4E3</td>
<td>2.4E3</td>
</tr>
</tbody>
</table>

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

INITIAL MEAN VALUE +GAIN(DB) = +1.31X10⁰²
DEVI CE TYPE: OP-27 OP AMP
MFG: LTC 5 DEVICES TEST DATE 05-15-66
REF: JPL LOG 2142 DATE CODE 6578

TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE (rads)</th>
<th>Time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>10.31</td>
</tr>
<tr>
<td>1.0E5</td>
<td>XXXX</td>
</tr>
<tr>
<td>3.0E6</td>
<td>XXXXXXXXXXXX</td>
</tr>
<tr>
<td>1.0E7</td>
<td>XXXXXXXXXXXX</td>
</tr>
<tr>
<td>4.6E8</td>
<td>XXXXXXXXXXXX</td>
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<tr>
<td>7.2E9</td>
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<td>2.4E10</td>
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<tr>
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</table>

INITIAL MEAN VALUE -GAIN (DB) = +1.49X10^2

5-181
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSE, rads(Si)</td>
<td>CO60 Gammas</td>
</tr>
<tr>
<td>3.0E4</td>
<td>1.5E5</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>0.0020</td>
</tr>
<tr>
<td>DOSE/HOURS</td>
<td>7.2E1</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>0.0042</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(Si) Co\textsuperscript{60} Gammas</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E+4</td>
<td>7.5E+4 1.5E+5 3.0E+5 6.0E+5 1.0E+6 2.0E+6 1.0E+0 3.0E+0 6.0E+0 2.4E+1</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>7.670 14.57 26.75 29.04 3.053 17.65 20.38 25.45 32.97 37.64 39.65</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(Si) Co\textsuperscript{60} Gammas</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2E+1</td>
<td>2.4E+2 7.2E+2</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>35.77 23.75 20.12</td>
<td></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 8350

(3) IB IN NA 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>3.0E4 7.5E4 1.5E5</td>
<td>3.0E5 6.0E5 1.0E6 2.0E6 1.0E6 3.0E6 6.0E6 2.4E1</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>13.07 22.47 6.149</td>
<td>39.86 28.00 22.74 34.64 40.35 52.36 68.74 62.60</td>
</tr>
<tr>
<td>7.2E1</td>
<td>7.2E1 2.4E2 7.2E2</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>54.90 23.11 19.16</td>
<td></td>
</tr>
</tbody>
</table>

5-184
DEVI CE TYPE: OP-27 OP AMP
MFG: MPS 4 DEVICES TEST DATE 06-11-86
REF: JPL LOG 1147 DATE CODE 6350

(4) +GAIN (1K LOAD=10MA, 110V) IN DB VS DOSE

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 3.0E6 8.0E6 2.4E1</th>
</tr>
</thead>
</table>

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

INITIAL MEAN VALUE +GAIN (DB) = +1.26X10^-9
DEVICE TYPE: UP-27 UP AMP
MFG: MPS 4 DEVICES TEST DATE 06-11-66
REF: JPL LOG 1147 DATE CODE 8-350

DOSE, rads (Si) Co60 Gammas TIME, hours

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>TIME, hours</th>
<th>STD. DEV.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E4</td>
<td>1.0E6</td>
<td>2.4E1</td>
</tr>
<tr>
<td>7.5E4</td>
<td>1.0E6</td>
<td>2.4E1</td>
</tr>
<tr>
<td>1.5E5</td>
<td>1.0E6</td>
<td>2.4E1</td>
</tr>
<tr>
<td>3.0E5</td>
<td>1.0E6</td>
<td>2.4E1</td>
</tr>
<tr>
<td>6.0E5</td>
<td>1.0E6</td>
<td>2.4E1</td>
</tr>
</tbody>
</table>

STD. DEV. = 1.249

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

5-186
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>6.0E5</td>
<td>1.0E6</td>
</tr>
<tr>
<td>2.0E6</td>
<td>1.0E6</td>
</tr>
<tr>
<td>3.0E6</td>
<td>6.0E6</td>
</tr>
<tr>
<td>2.4E1</td>
<td>2.4E1</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>.0130 .0434</td>
</tr>
<tr>
<td></td>
<td>.1665 .1665</td>
</tr>
<tr>
<td></td>
<td>.2199 .1162</td>
</tr>
<tr>
<td></td>
<td>.1063 .0980</td>
</tr>
<tr>
<td></td>
<td>.0693 .0533</td>
</tr>
</tbody>
</table>

<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></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>.0489 .0277</td>
</tr>
<tr>
<td></td>
<td>.0225</td>
</tr>
</tbody>
</table>
DEVICE Type: OP-27 OP AMP
MFG: RAY 5 DEVICES TEST DATE 06-11-86
REF: JPL LOG 1188 DATE CODE 8230

DOSE, rads(Si) Co60 Gammas TIME, hours

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>DOSE, rads(Si)</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</td>
<td>2.4E1, 2.4E2</td>
<td>7.2E1</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>62.67, 195.5, 296.4, 287.9, 147.2, 226.0, 221.6, 226.0, 254.1, 266.4, 313.5</td>
<td></td>
</tr>
</tbody>
</table>

TABLE OF NORMAL STANDARD DEVIATIONS
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>DOSE/HOURS (mSv)</th>
<th>TIME, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.004 7.5e-4 1.5e-3 3.2e-3 6.2e-3 1.0e-2 2.0e-2 1.0e0 3.0e0 6.0e0</td>
<td>2.4e1</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>52.92 166.0 581.6 491.6 491.4 433.0 491.6 414.9 360.5 311.5 227.6</td>
</tr>
<tr>
<td>DOSE/HOURS</td>
<td>7.2e1 2.4e2 7.2e2</td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>166.1 126.1 97.92</td>
</tr>
</tbody>
</table>
DEVICE TYPE: UP-27 UP AMP
MFG: PAN 5 DEVICES TEST DATE 06-11-86
REF: JPL LOG 1168 DATE CODE 8230

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

<table>
<thead>
<tr>
<th>DOSE/HOURS</th>
<th>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E7 3.0E7 6.0E7 2.4E8</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>1.131 1.264 1.603 3.366 2.737 2.771 2.936 2.909 2.610 6.159 1.603</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE GAIN(DB) = +1.24X10^2
**DEVICE TYPE:** OP-27 OP AMP  
**MFG. RAY** 3 DEVICES  
**TEST DATE** 06-11-86  
**REF:** JPL LOG 1186  
**DATE CODE** 6230

---

**TABLE OF NORMAL STANDARD DEVIATIONS**

<table>
<thead>
<tr>
<th>I (mA)</th>
<th>DOSE, rads(SI)</th>
<th>TIME, hours</th>
<th>Dose/Hours</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>3.0E4 7.5E4 1.5E5 3.0E5 6.0E5 1.0E6 2.0E6 1.0E6 3.0E6 6.0E6 2.4E7</td>
<td>1.294 1.216 .5166 .6353 .7727 .7727 .9690 1.173 1.065 1.395 .7727</td>
<td>7.2E1 2.4E2 7.2E2</td>
<td>.6334 1.616 1.309</td>
</tr>
</tbody>
</table>

**INITIAL MEAN VALUE - GAIN (DE) = +1.24X10^2**

---

**GRAPH:**
- **Y-axis:** MEAN - GAIN (DB)  
- **X-axis:** DOSE, rads(SI) Co60 Gammas  
- **EOP** vs TIME, hours

---

**Notes:**
- PRE-RAD values are shown with respective Rad and Hours values.
DEVICE TYPE: OPA111 FET-INPUT OP-AMP

MB: 505 5 DEVICES TEST DATE 10-17-85
REF: JPL LOG 1196 DATE CODE 6449

DOSE, rads(Si) 2.5 MeV electrons

(1) VOS IN MV VS DOSE

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Dose, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>0.000 1.565 3.065 6.065 1.066 3.066 1.067</td>
</tr>
<tr>
<td>STD. DEVI.</td>
<td>0530 0745 2361 4535 6649 1679 3080</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE VOS(MV) = \( +3.57 \times 10^{-2} \)

5-192
DEVICE TYPE: OPA111 FET-INPUT OP-AMP
REF: JPL LOG 1196 DATE CODE 6449

DOSE, rads(Si) 2.5 MeV electrons

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rads(Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD. DEV.</td>
<td>1163 2466 2688 5630 1178 9390 2771</td>
</tr>
</tbody>
</table>

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

5-193
DEVICE TYPE: OPA111 FET-INPUT OP-AMP
MFG: BU1  5 DEVICES  TEST DATE 10-17-85
REF: JPL L06 1196  DATE CODE 8449

<table>
<thead>
<tr>
<th>CURVE</th>
<th>DOSE, rods(Si)</th>
<th>2.5 MeV electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>0.000 1.565 3.065 6.065 1.066 3.066 1.067</td>
<td></td>
</tr>
<tr>
<td>STD. DEV.</td>
<td>4.52 2.04 3.95 6.44 10.07 21.14 56.64</td>
<td></td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE 1B(µA) = +1.10x10⁻¹
DEVICE TYPE: OPA111 FET-INPUT OP-AMP

MFG: BUB 3 DEVICES TEST DATE 10-09-65
REF: JPL L06 1199 DATE CODE 6449

DOSE, rads(Si) Co-60 Gamma
(2) I0S 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>0.000 1.5E-5 3.0E-5 6.0E-5 1.0E6 3.0E6 1.0E7</td>
<td>.3481 .2564 .3916 .5164 .1665 1.051 1.172</td>
</tr>
</tbody>
</table>

INITIAL MEAN VALUE I0S(PA) = +6.86X10^3
TABLE OF NORMAL STANDARD DEVIATIONS

<table>
<thead>
<tr>
<th>CURVE</th>
<th>Dose, rods(Si) Co^{60} Gammas</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>0.000 0.003 0.006 0.009 0.012 0.015 0.018 0.021</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3627 2143 5341 1335 1269 66.61 74.61</td>
<td></td>
</tr>
</tbody>
</table>

Initial mean value IB(PA) = 1.45 x 10^{-3}
APPENDIX A

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

ELECTRICAL PARAMETER SYMBOLS AND ABBREVIATIONS
**ELECTRICAL PARAMETER SYMBOLS AND ABBREVIATIONS**

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