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DATE: April 23, 1998 PPM-98-008
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SUBJECT: Radiation Report on **OP15 (Analog Devices) (LDC 9722A)**
PROJECT: GOES (ITT)

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A radiation evaluation was performed on **OP15 Precision, JFET-Input Operational Amplifier (Analog Devices)** to determine the total dose tolerance of these parts. The total dose testing was performed using a $Co^{60}$ gamma ray source. During the radiation testing, eight parts were irradiated under bias (see Figure 1 for bias configuration) and three parts were used as control samples. The total dose radiation levels were 20.0, 40.0, 60.0, 80.0, 100.0, 150.0, and 200.0 kRads.[1] The dose rate was 1.200 kRads/hour (0.333 Rads/s). See Table II for the radiation schedule and effective dose rate calculation. After the 200.0 kRad irradiation, the parts were annealed under bias at 25°C[2] and tested at 4, 24 and 168 hours. After each radiation exposure and annealing treatment, parts were electrically tested according to the test conditions and the specification limits[3] listed in Table III. An executive summary of the test results is provided below in bold; followed by a detailed summary of the test results after each radiation level and annealing step. For detailed information, refer to Tables I through IV and Figures 1 through 3.

**All irradiated parts except one stayed within the specification limits for all tests on irradiation to 40 kRads. One part marginally exceeded the specification limits for VOS after 20 and 40 kRads exposures. After the 60 to 200 kRad exposures, some parts exceeded the specification limits for VOS and all parts exceeded the specification limits for ± Ibias, and Iio. After annealing the parts at 25°C for 4, 24 and 168 hours, the parts showed some increase in VOS and some recovery in ±Ibias. Figures 2 and 3 show the degradation in the radiation sensitive parameters VOS and Ibias with increasing radiation exposure. The increased degradation in VOS with annealing at 25°C indicates that the parts may show more degradation in the low dose rates of the space environment. A detailed summary of test results is provided below.**

Initial electrical measurements were made on 11 samples. Eight samples (SN's 1150, 1153, 1154, 1155, 1157, 1207, 1218, and 1219) were used as radiation samples while SN's 1151, 1152 and 1220 were used as control samples. All parts passed all tests during initial electrical measurements.

After the 20.0 kRad irradiation, SN 1218 marginally exceeded the specification limit of 500µV for VOS with a reading of 505µV. **All parts passed all other tests.**

After the 40.0 kRad irradiation, SN 1218 continued to marginally exceed the specification limit for VOS with a reading of 692µV. **All parts passed all other tests.**

After the 60.0 kRad irradiation, three parts marginally exceeded the specification limit for VOS with readings in the range of 504 to 823µV. All parts exceeded the specification limit of 50pA for –Ibias with readings in the range of 600 to 750pA. The bench measurements of ±Ibias became somewhat unstable (readings could not be repeated to less than 20pA); therefore, $I_{IO}$ became difficult to calculate at this level and remained so throughout the rest of the testing. **All parts passed all other tests.**

After the 80.0 kRad irradiation, three parts exceeded the specification limit for VOS with readings in the range of 520 to 849µV. All parts exceeded the specification limit of 50pA for ±Ibias with readings in the range of 630 to

[1] The term Rads, as used in this document, means Rads (silicon). All radiation levels cited are cumulative.
[2] The temperature 25°C as used in this document implies room temperature.
[3] These are manufacturer's pre-irradiation data specification limits. The manufacturer provided no post-irradiation limits at the time these tests were performed.

800pA for both. Due to continuing instability in Ibias measurements, $I_{IO}$ could not be calculated accurately but several parts could be considered to exceed the specification limit of 10pA. **All parts passed all other tests.**

After annealing the parts for 72 hours at 25°C, parts showed some increase in VOS with five parts exceeding the specification limit for VOS with readings in the range of 642 to 1095μV. Marginal recovery was seen in ±Ibias with readings in the range of 400 to 580pA for both. Most parts exceeded the specification limit for $I_{IO}$ with readings in the range of 10 to 20pA.

After the 100.0 kRad irradiation, all parts exceeded the specification limit for VOS with readings in the range of 692 to 1655μV. All parts exceeded the specification limit for ±Ibias with readings in the range of 630 to 815pA for both. Most parts exceeded the specification limit for $I_{IO}$ with readings in the range of 10 to 25pA. **All parts passed all other tests.**

After the 150.0 kRad irradiation, all parts exceeded the specification limit for VOS with readings in the range of 1039 to 2409μV. All parts exceeded the specification limit for ±Ibias with readings in the range of 1200 to 1600pA for both. All parts exceeded the specification limit for $I_{IO}$ with readings in the range of 20 to 100pA. **All parts passed all other tests.**

After the 200.0 kRad irradiation, all parts exceeded the specification limit for VOS with readings in the range of 1173 to 2940μV. All parts exceeded the specification limit for ±Ibias with readings in the range of 850 to 1200pA for both. All parts exceeded the specification limit for $I_{IO}$ with readings in the range of 20 to 100pA. **All parts passed all other tests.**

After annealing the parts for 4 hours at 25°C, parts showed marginal recovery in VOS with readings in the range of 1144 to 2901μV, and no significant change in ±Ibias.

After annealing the parts for 24 hours at 25°C, parts showed increased degradation in VOS with readings in the range of 1691 to 4021μV, and no significant change in ±Ibias.

After annealing the parts for 168 hours at 25°C, parts continued to show increased degradation in VOS with readings in the range of 2126 to 5704μV, and some recovery in ±Ibias. $I_{IO}$ showed some recovery with only two parts failing with readings of 90 and 150pA.

**The increased degradation in VOS with annealing indicates that the parts may show more degradation in the low dose rates of the space environment.**

Table IV provides a summary of the test results with the mean and standard deviation values for each parameter after each irradiation exposure and annealing step.

Any further details about this evaluation can be obtained upon request. If you have any questions, please call us at (301) 731-8954.

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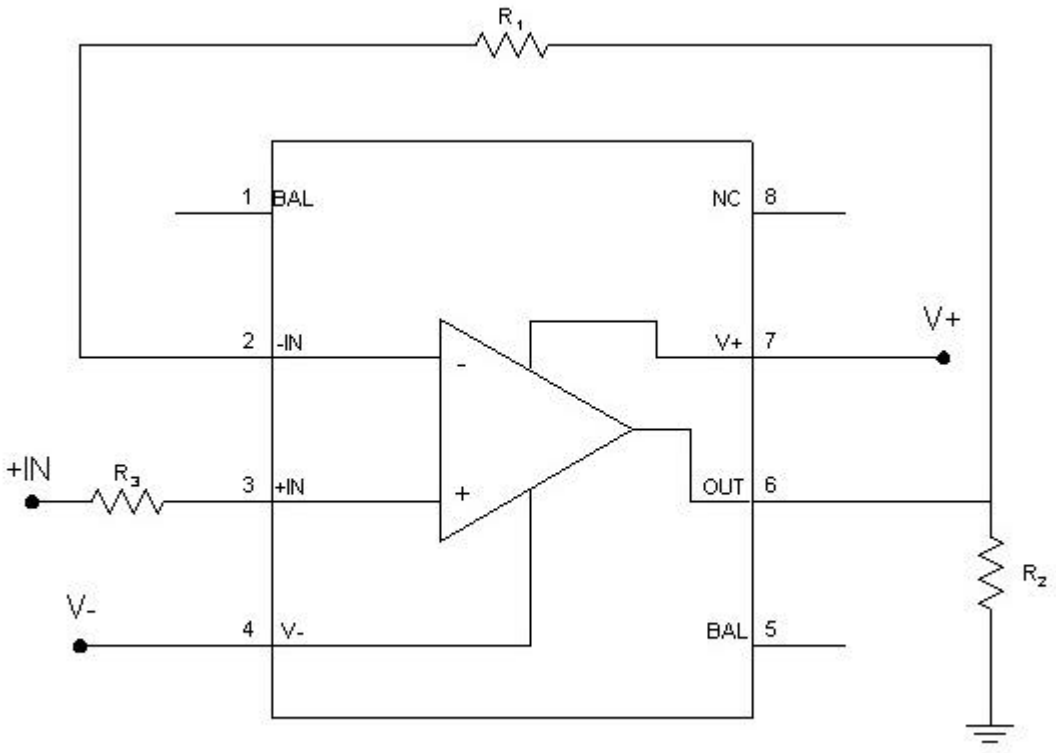
Figure 1. Radiation Bias Circuit for OP15




Notes:
1. $R_1$ & $R_2$ are 10kΩ ±10%, ¼W.
2. $R_3$ is 300Ω ±10%, ¼W.
3. +IN = +3.0V, +V = +20V, -V = -20V.

TABLE I. Part Information

| | |
|---|---|
| Generic Part Number: | OP15 |
| GOES ITT Part Number | OP15 |
| Charge Number: | C80709 |
| Manufacturer: | Analog Devices |
| Lot Date Code (LDC): | 9722A |
| Quantity Tested: | 11 |
| Serial Number of Control Samples: | 1151, 1152, 1220 |
| Serial Numbers of Radiation Samples: | 1150, 1153, 1154, 1155, 1157, 1207, 1218, and 1219 |
| Part Function: | Precision, JFET-Input Operational Amplifier |
| Part Technology: | Bipolar/JFET |
| Package Style: | 8-Pin DIP |
| Test Equipment: | A540/Bench Tests |
| Test Engineer: | S. Archer-Davies |

- The manufacturer for this part guaranteed no radiation tolerance/hardness.

TABLE II. Radiation Schedule for OP15

| EVENT | DATE |
|---|---|
| 1) INITIAL ELECTRICAL MEASUREMENTS | 03/23/98 |
| 2) 20.0 KRAD IRRADIATION (1.200 KRADS/HOUR) | 03/23/98 |
| POST-20.0 KRAD ELECTRICAL MEASUREMENT | 03/24/98 |
| 3) 40.0 KRAD IRRADIATION (1.200 KRADS/HOUR) | 03/24/98 |
| POST-40.0 KRAD ELECTRICAL MEASUREMENT | 03/25/98 |
| 4) 60.0 KRAD IRRADIATION (1.200 KRADS/HOUR) | 03/25/98 |
| POST-60.0 KRAD ELECTRICAL MEASUREMENT | 03/26/98 |
| 5) 80.0 KRAD IRRADIATION (1.200 KRADS/HOUR) | 03/26/98 |
| POST-80.0 KRAD ELECTRICAL MEASUREMENT | 03/27/98 |
| 6) 72 HOUR ANNEALING @25°C * | 03/27/98 |
| POST-72 HOUR ANNEAL ELECTRICAL MEASUREMENT | 03/30/98 |
| 7) 100.0 KRAD IRRADIATION (1.200 KRADS/HOUR) | 03/30/98 |
| POST-100.0 KRAD ELECTRICAL MEASUREMENT | 03/31/98 |
| 8) 150.0 KRAD IRRADIATION (1.200 KRADS/HOUR) | 04/31/98 |
| POST-150.0 KRAD ELECTRICAL MEASUREMENT | 04/02/98 |
| 9) 200.0 KRAD IRRADIATION (0.450 KRADS/HOUR) ** | 04/02/98 |
| POST-200.0 KRAD ELECTRICAL MEASUREMENT | 04/06/98 |
| 10) 4 HOUR ANNEALING @25°C | 04/06/98 |
| POST-4 HOUR ANNEAL ELECTRICAL MEASUREMENT | 04/06/98 |
| 11) 24 HOUR ANNEALING @25°C | 04/06/98 |
| POST-24 HOUR ANNEAL ELECTRICAL MEASUREMENT | 04/07/98 |
| 12) 168 HOUR ANNEALING @25°C | 04/07/98 |
| POST-168 HOUR ANNEAL ELECTRICAL MEASUREMENT | 04/14/98 |

Effective Dose Rate = 200,000 RADS/14 DAYS=595.2 RADS/HOUR=0.165 RADS/SEC
The effective dose rate is lower than that of the individual radiation steps as it takes into account the interim-annealing step.

* This 72 hour annealing step was added to maintain the prescribed dose rate due to the weekend.
** The dose rate was adjusted to allow the parts to receive radiation dose over the weekend.

PARTS WERE IRRADIATED AND ANNEALED UNDER BIAS, SEE FIGURE 1.

Table III. Electrical Characteristics of OP15 /1

| Test # | Parameter | Units | Test Conditions | Spec. min | Lim. max |
|---|---|---|---|---|---|
| 1 | +Icc | mA | $+V_S$ = 15V | 0.0 | 4.0 |
| 2 | -Icc | mA | $-V_S$ = -15V | -4.0 | 0.0 |
| 3 | Power_Diss | mW | $V_{CC}$ = ±15V, $V_O$ = 0V | | 120 |
| 4 | VOS | µV | $+V_S$ = 15V, $-V_S$ = -15V, $R_S$ = 50Ω | -500 | 500 |
| 5 | CMRR | dB | $V_{CM}$ = ±10.5V | 86 | |
| 6 | PSRR | dB | $+V_S$ = ±10V to ±18V | 84 | |
| 7 | P_VOUT_10k | V | $R_L$ = 10kΩ | 12.0 | |
| 8 | N_VOUT_10k | V | $R_L$ = 10kΩ | | -12.0 |
| 9 | P_VOUT_2k | V | $R_L$ = 2kΩ | 11.0 | |
| 10 | N_VOUT_2k | V | $R_L$ = 2kΩ | | -11.0 |
| 11 | P_AOL_2k | V/mV | $R_L$ = 2kΩ, $V_O$ = +10V | 100 | |
| 12 | N_AOL_2k | V/mV | $R_L$ = 2kΩ, $V_O$ = -10V | 100 | |
| 13 | Slew Rate | V/µs | AVCL = 1 | 10.0 | |
| 14 | +Ibias /2 | pA | $+V_S$ = 15V, $-V_S$ = -15V | -50 | 50 |
| 15 | -Ibias /2 | pA | $+V_S$ = 15V, $-V_S$ = -15V | -50 | 50 |
| 16 | Iio /2 | pA | $+V_S$ = 15V, $-V_S$ = -15V | -10 | 10 |

Notes:

1/ These are the manufacturer's non-irradiated data sheet specification limits. The manufacturer provided no post-irradiation limits at the time the tests were performed.

2/ Due to limitations in the automatic test equipment, ±Ibias and Iio were measured on the bench.

## TABLE IV: Summary of Electrical Measurements after Total Dose Exposures and Annealing for OP15 /1

| | | | | | Total Dose Exposure (kRads Si) | | | | | | | | | | Annealing | | Total Dose Exposure (kRads Si) | | | | | | Annealing | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test | | | Spec. Lim. /2 | | Initial | | 20.0 | | 40.0 | | 60.0 | | 80.0 | | 72 hours @25°C | | 100.0 | | 150.0 | | 200.0 | | 4 hours @25°C | | 24 hours @25°C | | 168 hours @25°C | |
| # | Parameters | Units | min | max | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd | mean | sd |
| 1 | +Icc | mA | 0.0 | 4.0 | 3.3 | 0.1 | 3.0 | 0.2 | 2.8 | 0.2 | 2.6 | 0.2 | 2.5 | 0.2 | 2.5 | 0.1 | 2.4 | 0.1 | 2.2 | 0.1 | 2.3 | 0.1 | 2.2 | 0.1 | 2.2 | 0.1 | 2.2 | 0.1 |
| 2 | -Icc | mA | -4.0 | 0.0 | -3.3 | 0.2 | -3.0 | 0.2 | -2.8 | 0.2 | -2.6 | 0.2 | -2.5 | 0.2 | -2.5 | 0.1 | -2.4 | 0.1 | -2.2 | 0.1 | -2.3 | 0.1 | -2.2 | 0.1 | -2.2 | 0.1 | -2.2 | 0.1 |
| 3 | Power_Diss | mW | | 120 | 50 | 2.4 | 45 | 2.3 | 42 | 5.5 | 39 | 2.5 | 37 | 1.9 | 39 | 2.1 | 35 | 1.9 | 34 | 1.8 | 34 | 1.7 | 34 | 1.3 | 33 | 1.2 | 33 | 0.9 |
| 4 | VOS | ?V | -500 | 500 | -70 | 201 | -19 | 216 | 165 | 205 | 409 | 248 | 443 | 255 | 769 | 256 | 1132 | 332 | 1622 | 474 | 1864 | 626 | 1736 | 658 | 2529 | 779 | 3499 | 1093 |
| 5 | CMRR | dB | 86 | | 101 | 2.4 | 101 | 2.5 | 102 | 2.8 | 102 | 3.3 | 103 | 3.9 | 105 | 5.5 | 110 | 14 | 103 | 4.7 | 103 | 4.7 | 105 | 5.5 | 102 | 4.8 | 106 | 13 |
| 6 | PSRR | dB | 84 | | 104 | 4.1 | 105 | 4.7 | 106 | 5.0 | 107 | 5.4 | 107 | 5.6 | 108 | 6.3 | 111 | 8.5 | 116 | 11 | 117 | 12 | 117 | 14 | 116 | 18 | 105 | 6.2 |
| 7 | P_VOUT_10k | V | 12.0 | | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 | 13.5 | 0 |
| 8 | N_VOUT_10k | V | | -12.0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 | -13.5 | 0 |
| 9 | P_VOUT_2k | V | 11.0 | | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 | 13.1 | 0 |
| 10 | N_VOUT_2k | V | | -11.0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 | -13.0 | 0 |
| 11 | P_AOL_2k | V/mV | 100 | | 396 | 42 | 344 | 27 | 322 | 29 | 302 | 25 | 289 | 19 | 305 | 24 | 282 | 19 | 266 | 17 | 276 | 14 | 284 | 20 | 285 | 16 | 307 | 19 |
| 12 | N_AOL_2k | V/mV | 100 | | 312 | 26 | 278 | 22 | 256 | 20 | 244 | 19 | 236 | 16 | 243 | 19 | 228 | 17 | 216 | 11 | 223 | 11 | 226 | 11 | 226 | 13 | 233 | 15 |
| 13 | Slew Rate | V/?s | 10.0 | | 19.5 | 4.1 | 24.9 | 2.4 | 24.8 | 2.6 | 24.9 | 2.5 | 24.8 | 2.4 | 24.6 | 2.4 | 24.1 | 2.3 | 25.5 | 2.4 | 25.5 | 2.5 | 25.0 | 2.6 | 24.8 | 1.9 | 25.2 | 2.6 |
| 14 | +Ibias /3 | pA | -50 | 50 | 1 | 0.5 | 1 | 0.9 | 3 | 2.1 | /4 | | 700 | 61 | 450 | 53 | 740 | 59 | 1400 | 132 | 1050 | 100 | 900 | 82 | 875 | 43 | 790 | 170 |
| 15 | -Ibias /3 | pA | -50 | 50 | -2 | 0 | -2 | 0 | -1 | 0.4 | 660 | 55 | 700 | 56 | 460 | 51 | 740 | 56 | 1400 | 111 | 1050 | 122 | 900 | 88 | 875 | 45 | 824 | 184 |
| 16 | Iio /3 /4 | pA | -10 | 10 | 2.3 | 0.2 | 2.7 | 0.5 | 4.8 | 1.7 | /4 | | /4 | | /4 | | /4 | | /4 | | /4 | | /4 | | /4 | | /4 | |

Notes:

1/ The mean and standard deviation values were calculated over the eight parts irradiated in this testing. The control samples remained constant throughout testing and are not included in this table.

2/ These are manufacturer's pre-irradiation data sheet specification limits. No post-irradiation limits were provided by the manufacturer at the time the tests were performed.

3/ These measurements were performed on the bench due to limitations in the automatic test equipment. (Can not measure below 1nA.)

4/ Due to instability in +Ibias and -Ibias, no reliable calculation of Iio was posible after 60 kRads.

**Radiation sensitive parameters: VOS, +/- Ibias, Iio.**

**Figure 2: VOS vs TID and Annealing for OP15**