ISL70444SEH

Total Dose Testing

AN1870
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Introduction and Executive Summary

This document reports the results of low and high dose rate total dose testing of the ISL70444SEH quad operational amplifier. The tests were conducted to provide an assessment of the total dose hardness of the part. Parts were irradiated under bias and with all pins grounded at low dose rate and under bias at high dose rate. The high dose rate samples were also taken out to the 50% overtest and subsequent anneal as described in MIL-STD-883 Test Method 1019. The anneal was performed under bias at an ambient temperature of 100°C for 168 hours.

The ISL70444SEH is acceptance tested on a wafer by wafer basis to 300krad(Si) at high dose rate (50–300rad(Si)/s) and to 50krad(Si) at low dose rate (0.01rad(Si)/s), insuring hardness to the specified level for both dose rates.

Given the excellent performance shown in the attributes and variables data, and in particular the stability shown by the key positive and negative input bias current parameters, the part is not considered dose rate sensitive. No significant differences in total dose response were noted between biased and grounded irradiation for any parameters, and all channels maintained variations within established limits in the pre-irradiation data or in the total dose response of the parts.

Reference Documents

- MIL-STD-883 test method 1019
- ISL70444SEH data sheet
- Standard Microcircuit Drawing (SMD) 5962–13214

Part Description

The ISL70444SEH features four low-power operational amplifiers optimized to provide maximum dynamic range. These op amps feature a unique combination of rail to rail operation on the input and output as well as a slew enhanced front end, providing ultra fast slew rates that are proportional to a given step size, increasing accuracy under transient conditions. The part also offers low power, low input offset voltage and low temperature drift, making it ideal for applications requiring both high DC accuracy and AC performance. With <5µs recovery from single event transients (SET) at an LET of 86.4MeV.cm^2/mg), the number of filtering components needed is drastically reduced. The ISL70444SEH is also immune to single event latch-up (SEL) as it is fabricated in Intersil's proprietary PR40 silicon on insulator (SOI) process. The part is designed to operate over a single supply range of 2.7V to 40V or a split supply voltage range of ±1.35V to ±20V. Applications for these amplifiers include precision payload instrumentation, data acquisition and precision power supply controls. The ISL70444SEH is available in a 14 lead hermetic ceramic flatpack and in die form. The ISL70444SEH offers guaranteed performance over the full -55°C to +125°C military temperature range. Key pre- and post-radiation specifications follow, with parametric limits shown for ±18V supplies.

- Input offset voltage . . . . ±400µV post-irradiation
- Input offset voltage TC . . . . 0.5µV/°C typical
- Input bias current. . . . . 370nA post-irradiation
- Supply current, per channel . . . . 2.4mA post-irradiation
- Gain-bandwidth product . . . . 19MHz typical
- Slew rate . . . . 60V/µs post-irradiation
- Operating temperature range. . . . .-55°C to +125°C

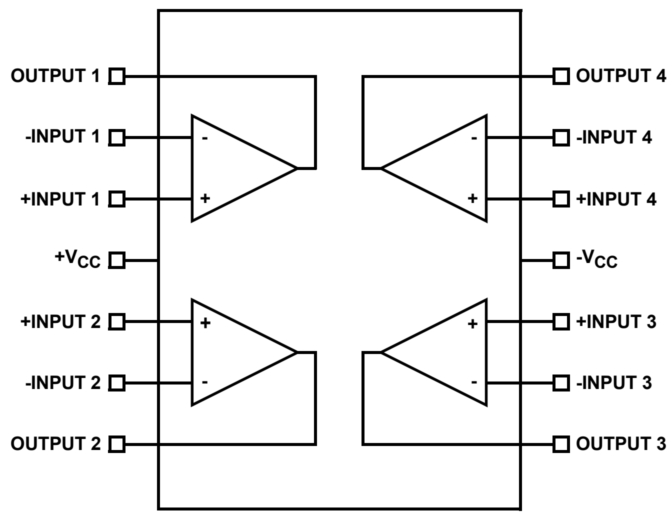


FIGURE 1. ISL70444SEH BLOCK DIAGRAM

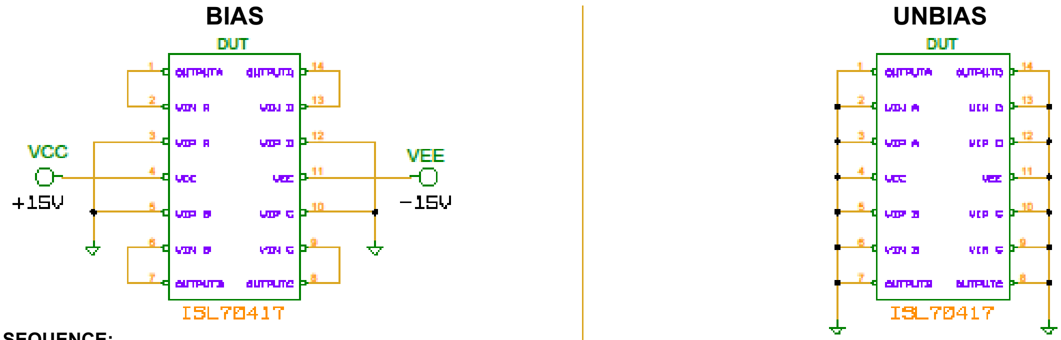
Test Description

Irradiation Facilities

High dose rate testing was performed at 69.7rad(Si)/s using a Gammacell 220 ^{60}Co irradiator located in the Palm Bay, Florida Intersil facility. Low dose rate testing was performed at 0.01rad(Si)/s using the Intersil Palm Bay N40 panoramic ^{60}Co irradiator. The post-high dose rate biased anneal operation was performed in a small temperature chamber.

Test Fixturing

Figure 2 shows the configuration and power supply sequencing used for biased irradiation. The grounded irradiations were performed in the same fixture type with all pins hardwired to ground.



POWER-UP SEQUENCE:
Bring up -1V supply, then +15V supply with ±5% tolerance.

POWER DOWN SEQUENCE:
Bring down +1V supply, then -15V supply.

FIGURE 2. BIASED AND UNBIASED (GROUNDED) IRRADIATION BIAS CONFIGURATIONS FOR THE ISL70444SEH. The figure shown is for the ISL70417SEH quad operational amplifier, and the ISL70444SEH uses the identical configuration.

Characterization Equipment and Procedures

All electrical testing was performed outside the irradiator using the production automated test equipment (ATE) with datalogging at each downpoint. Downpoint electrical testing was performed at room temperature. Three control units were used to improve repeatability.

Experimental Matrix

The experimental matrix consisted of five samples irradiated at low dose rate under bias, five samples irradiated at low dose rate with all pins grounded and five samples irradiated at high dose rate under bias. Samples of the ISL70444SEH were drawn from preproduction lot WW6XEH and were packaged in the hermetic 14-pin solder-sealed ceramic flatpack (K14.C) package. Samples were processed through the standard burnin cycle before irradiation, as required by MIL-STD-883, and were screened to the ATE limits at room temperature prior to the test.

Downpoints

Downpoints for the low dose rate tests were zero, 25 and 50krad(Si). Downpoints for the high dose rate tests were 0, 300 and 450krad(Si) followed by a 168 hour anneal under bias at 100°C.

Results

Test Results

Testing at low and high dose rate of the ISL70444SEH is complete. Table 1 shows the attributes data for the test.

Variables Data

The plots in Figures 3 through 16 show data at all downpoints including the post-anneal data. The plots show the response to total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. In addition the plots show the response of the high dose rate samples to a post-irradiation anneal at 100°C for 168 hours. We chose to plot the median for these parameters due to the relatively small sample size of five or six per experimental cell. “Discussion and Conclusion” on page 10 will provide individual discussion of the figures. No differences in total dose response were noted between biased and grounded irradiation for any parameters. Additionally, no channel to channel differences were noted, either in the pre-irradiation data or in the total dose response of the parts.

TABLE 1. ISL70444SEH TOTAL DOSE TEST ATTRIBUTES DATA.

DOSE RATE	BIAS	SAMPLE SIZE	DOWNPOINT	BIN 1	REJECTS
0.01rad(Si)/s	Figure 2	5	0	5	0
			25krad(Si)	5	0
			50krad(Si)	5	0
0.01rad(Si)/s	Grounded	5	0	5	0
			25krad(Si)	5	0
			50krad(Si)	5	0
69.7rad(Si)/s	Figure 2	5	0	5	0
			300krad(Si)	5	0
			450krad(Si)	5	0
			Anneal, 168h at 100°C	5	0

NOTES:

1. Bin 1 indicates a device that passes all pre-irradiation specification limits.
2. The 168-hour anneal was performed at 100°C under bias as shown in Figure 2.

Data Plots

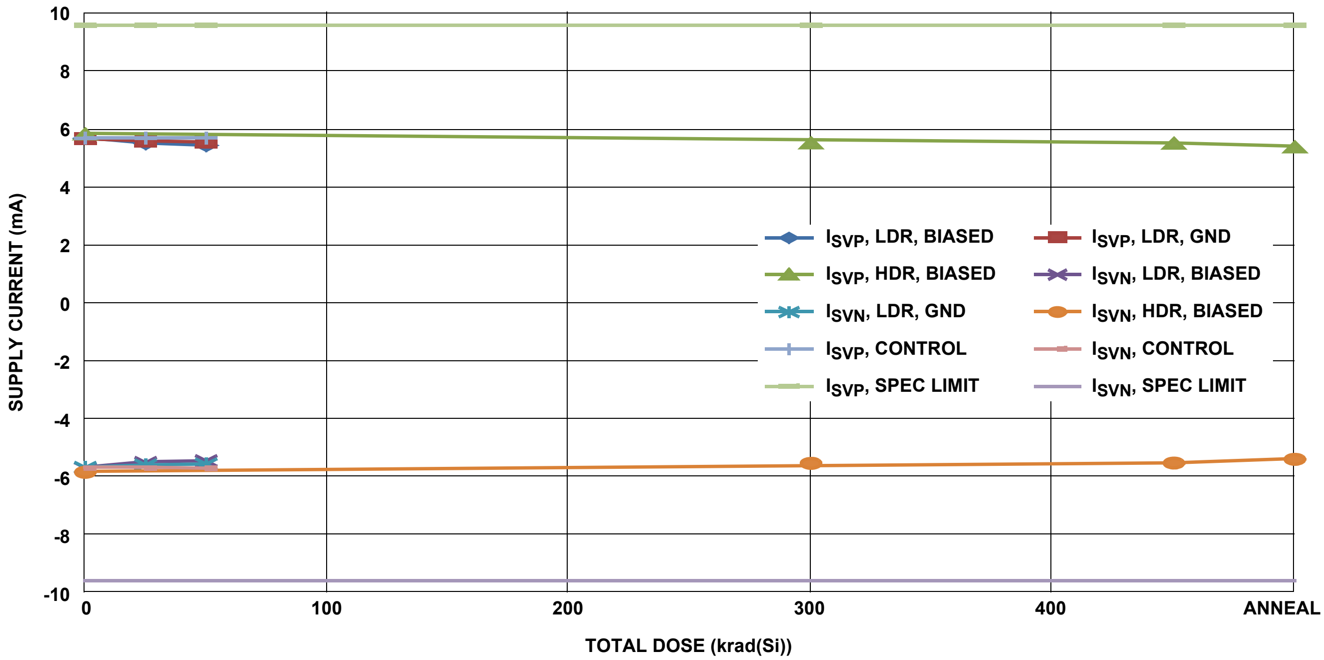


FIGURE 3. ISL70444SEH power supply current, sum of all four channels, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limits are +9.6mA (positive supply) and -9.6mA (negative supply).

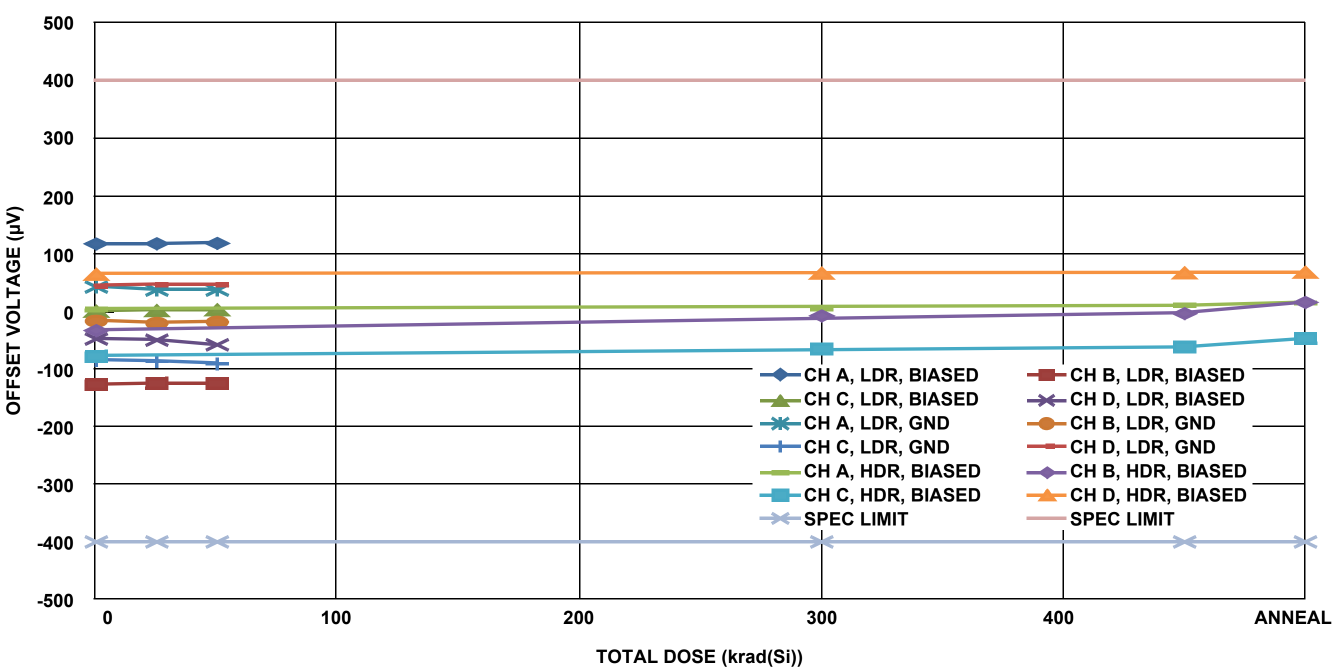


FIGURE 4. ISL70444SEH input offset voltage, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limits are -400µV to +400µV.

Data Plots (Continued)

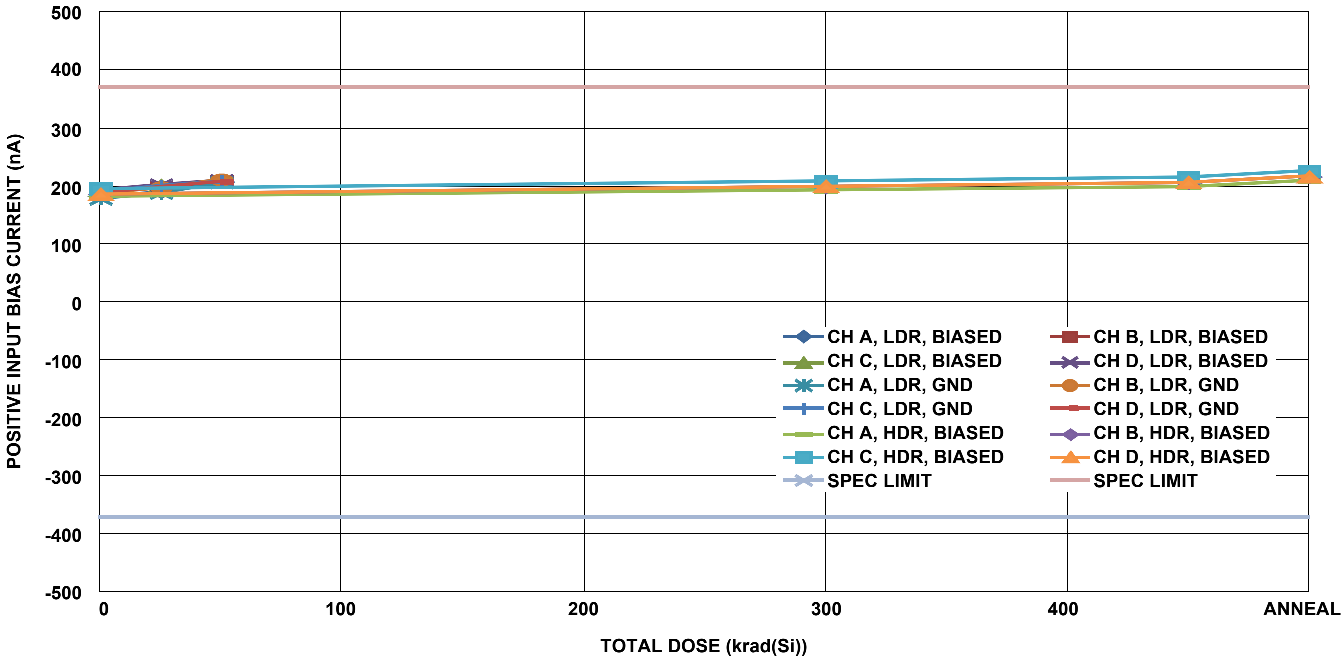


FIGURE 5. ISL70444SEH positive input bias current, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limits are -370nA to +370nA.

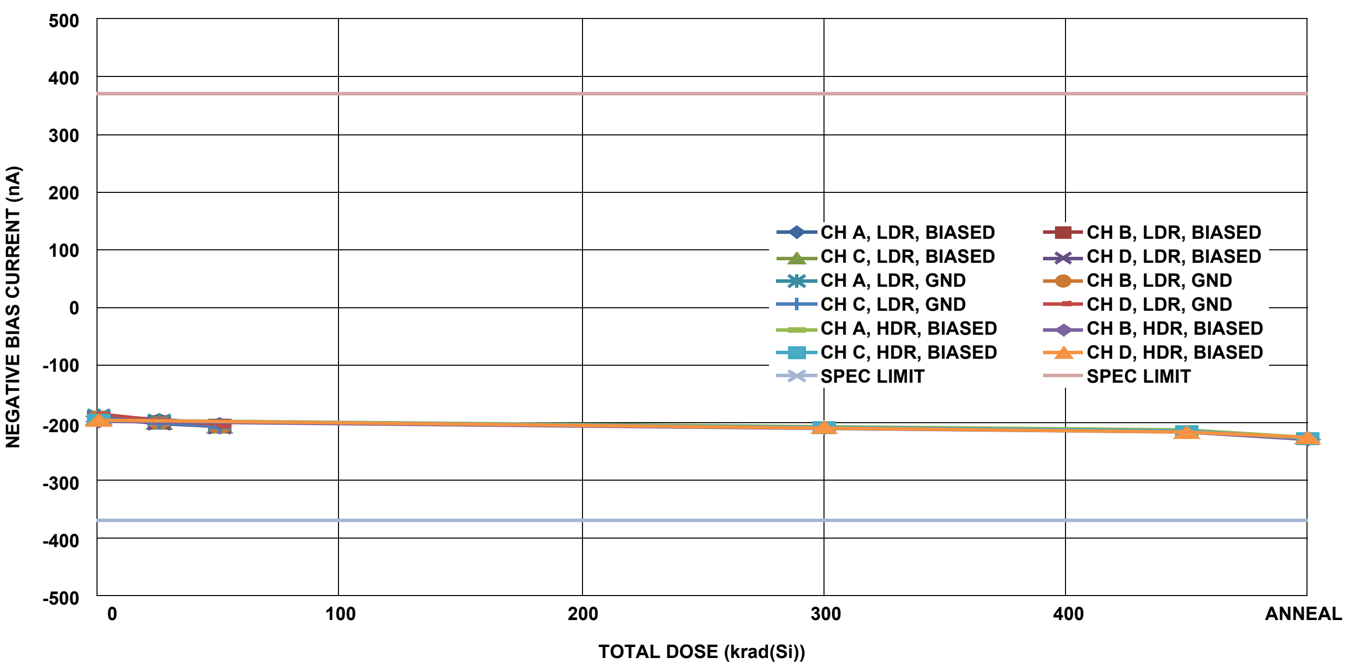


FIGURE 6. ISL70444SEH negative input bias current, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limits are -370nA to +370nA.

Data Plots (Continued)

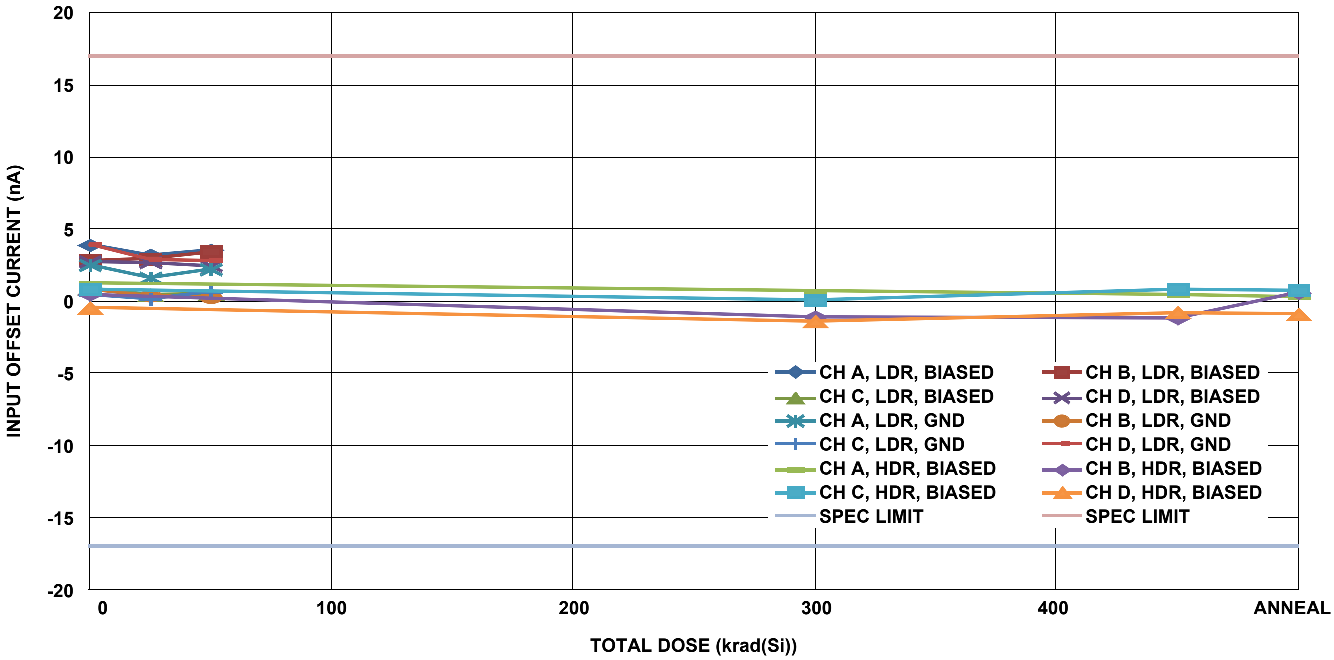


FIGURE 7. ISL70444SEH input offset current, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limits are -17nA to +17nA.

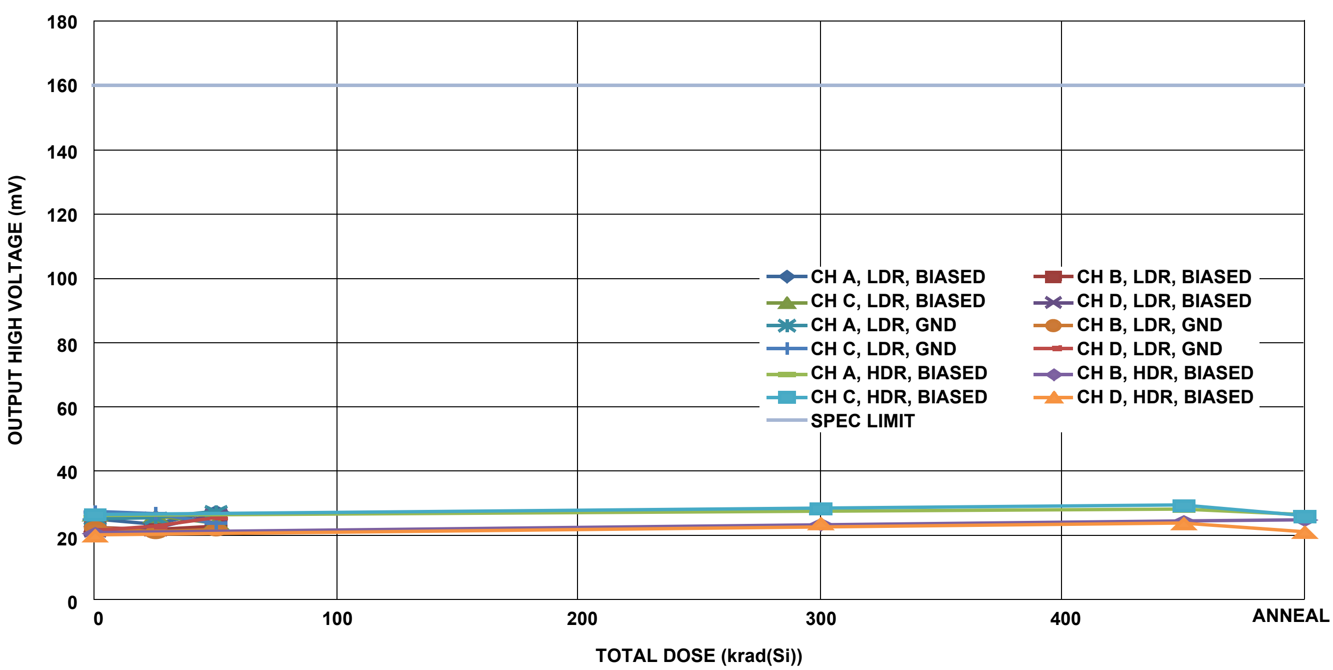


FIGURE 8. ISL70444SEH output high voltage, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 160mV maximum.

Data Plots (Continued)

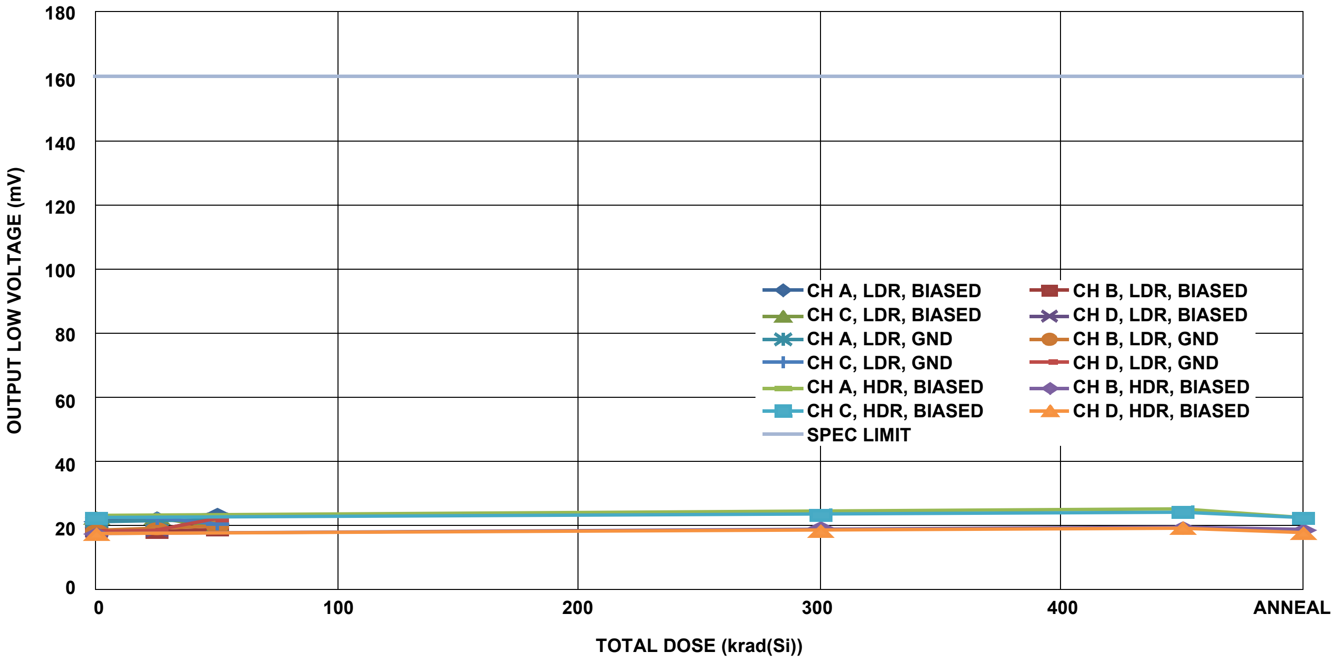


FIGURE 9. ISL70444SEH output low voltage, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 160mV maximum.

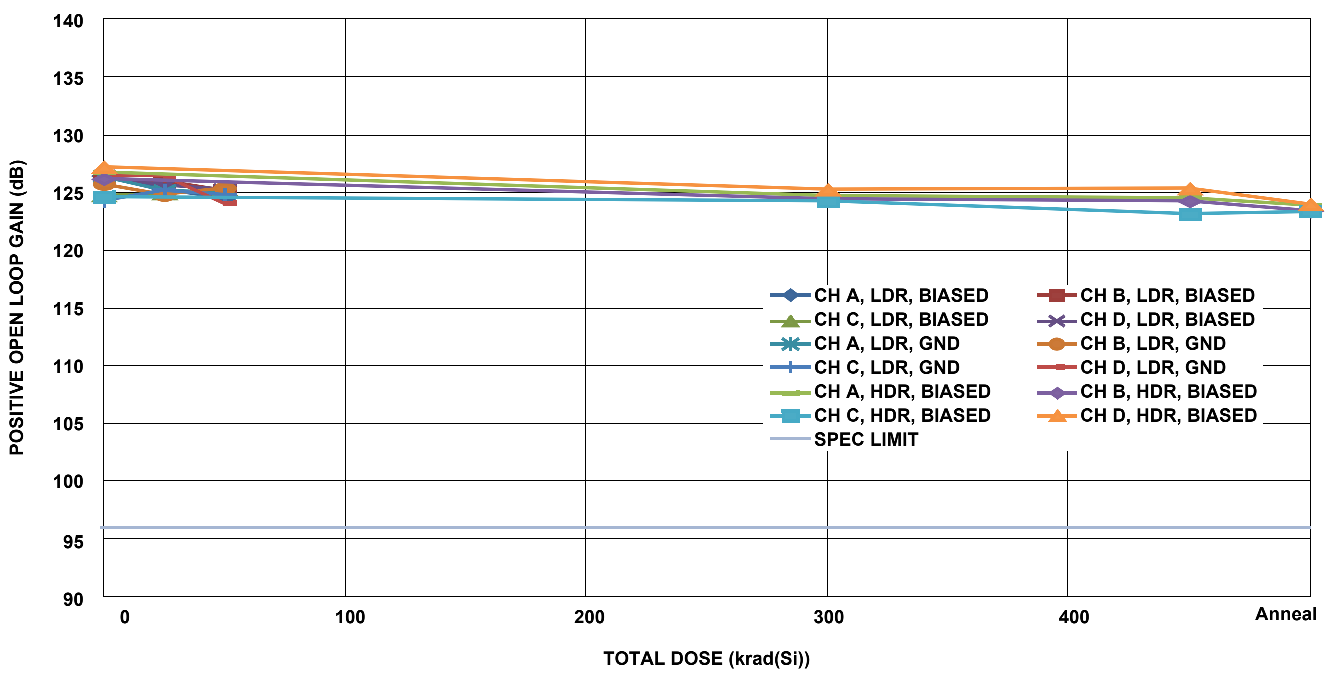


FIGURE 10. ISL70444SEH positive open loop gain, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 97dB minimum.

Data Plots (Continued)

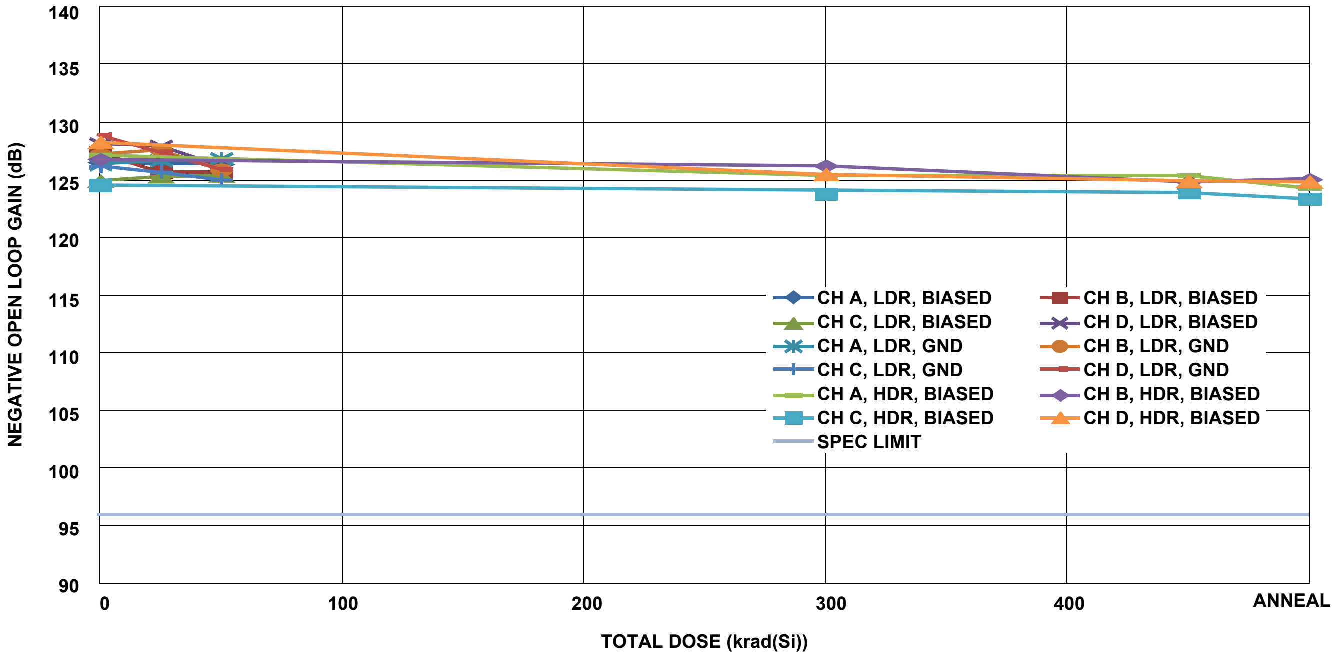


FIGURE 11. **ISL70444SEH** negative open-loop gain, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 97dB minimum.

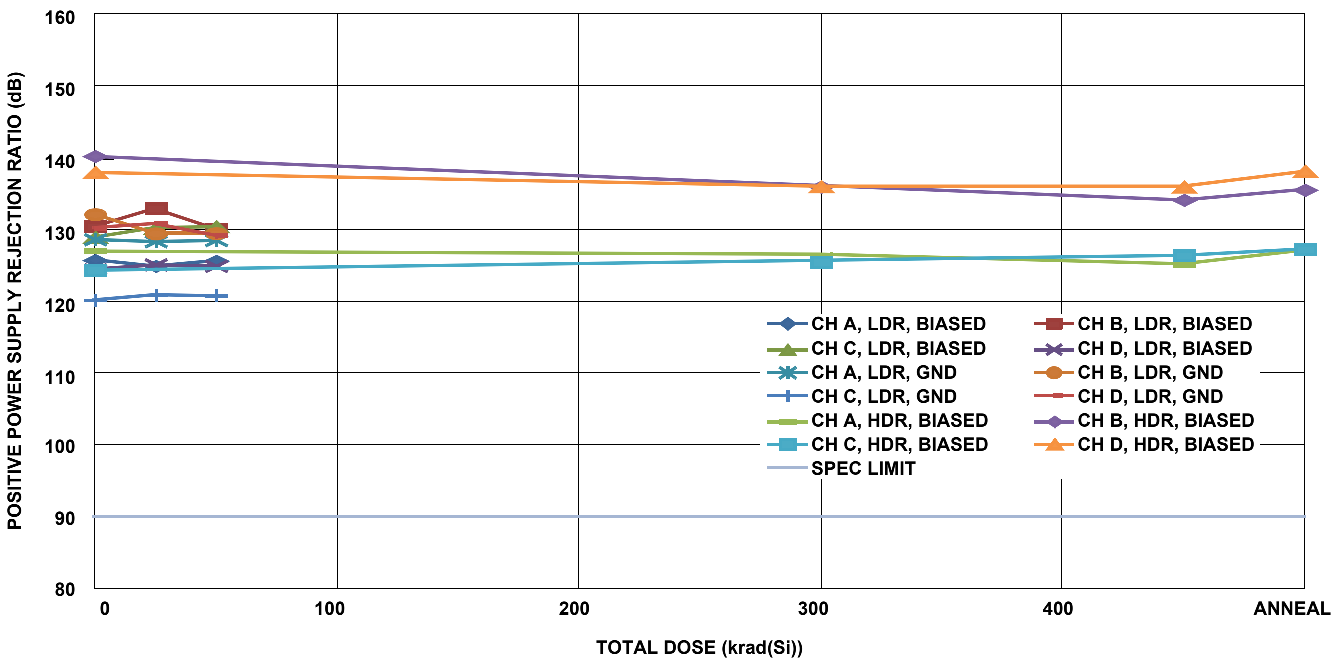


FIGURE 12. **ISL70444SEH** positive power supply rejection ratio, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 90dB minimum.

Data Plots (Continued)

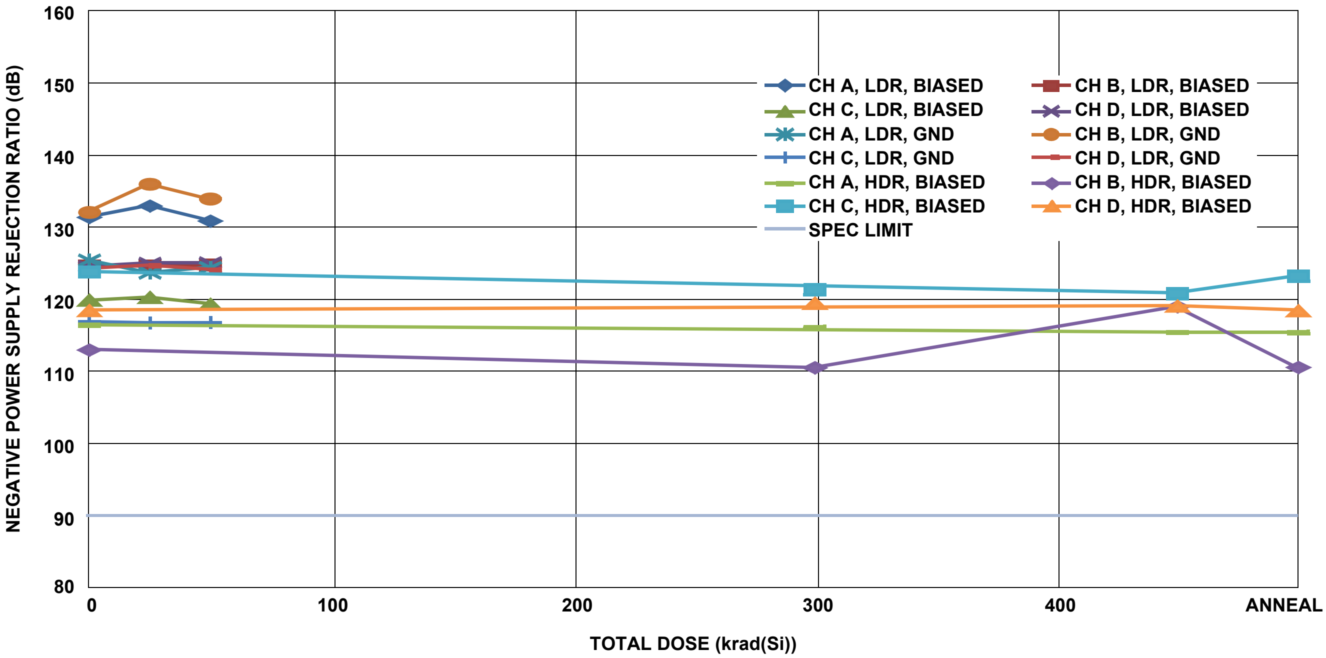


FIGURE 13. ISL70444SEH negative power supply rejection ratio, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 90dB minimum.

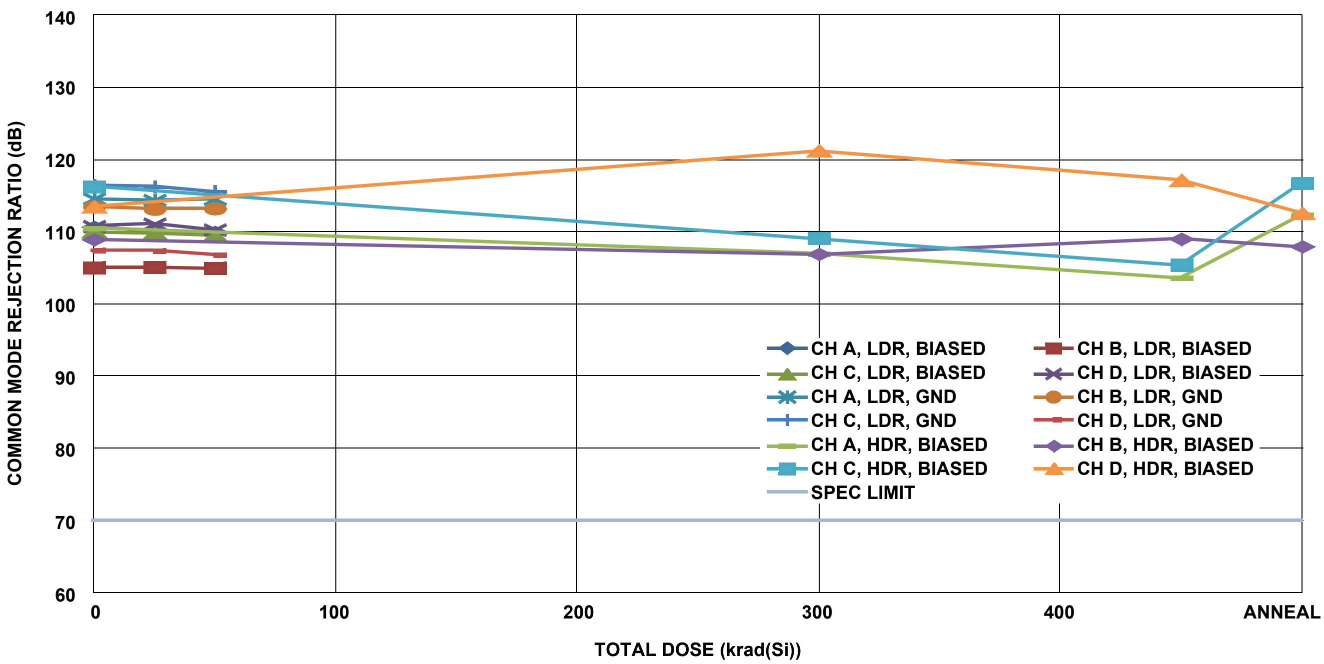


FIGURE 14. ISL70444SEH common mode rejection ratio, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 70dB minimum.

Data Plots (Continued)

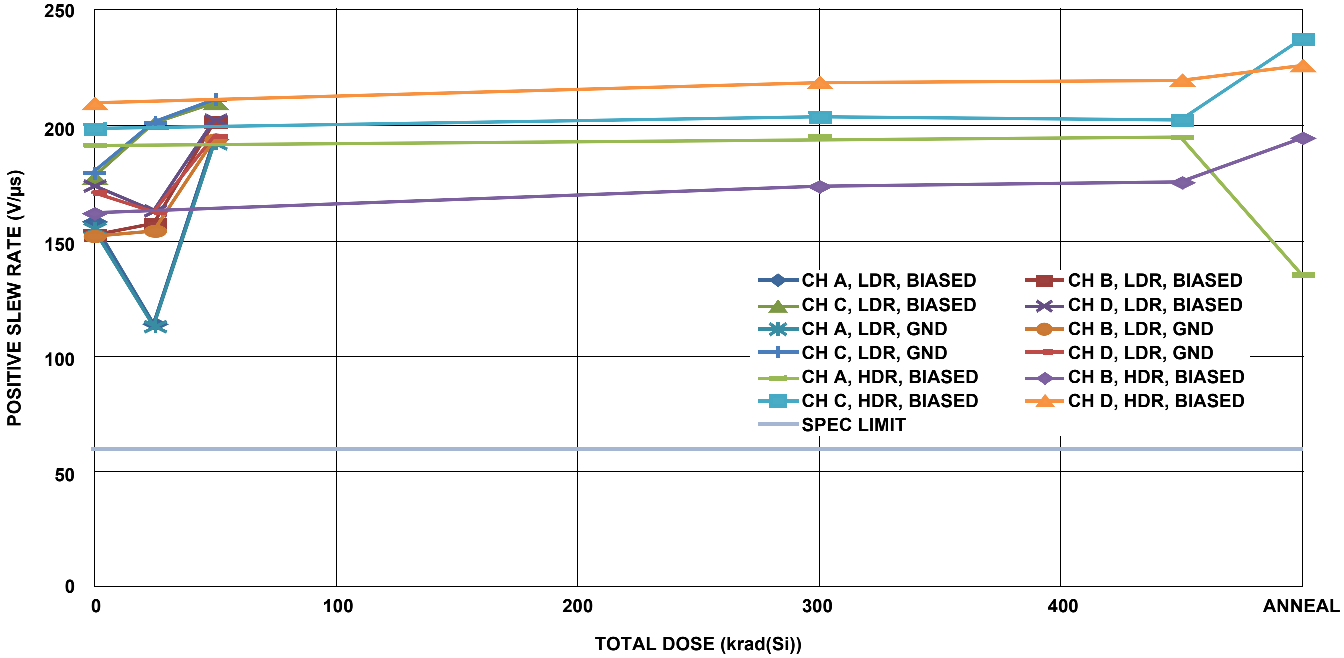


FIGURE 15. **ISL70444SEH** positive slew rate, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 60V/µs minimum.

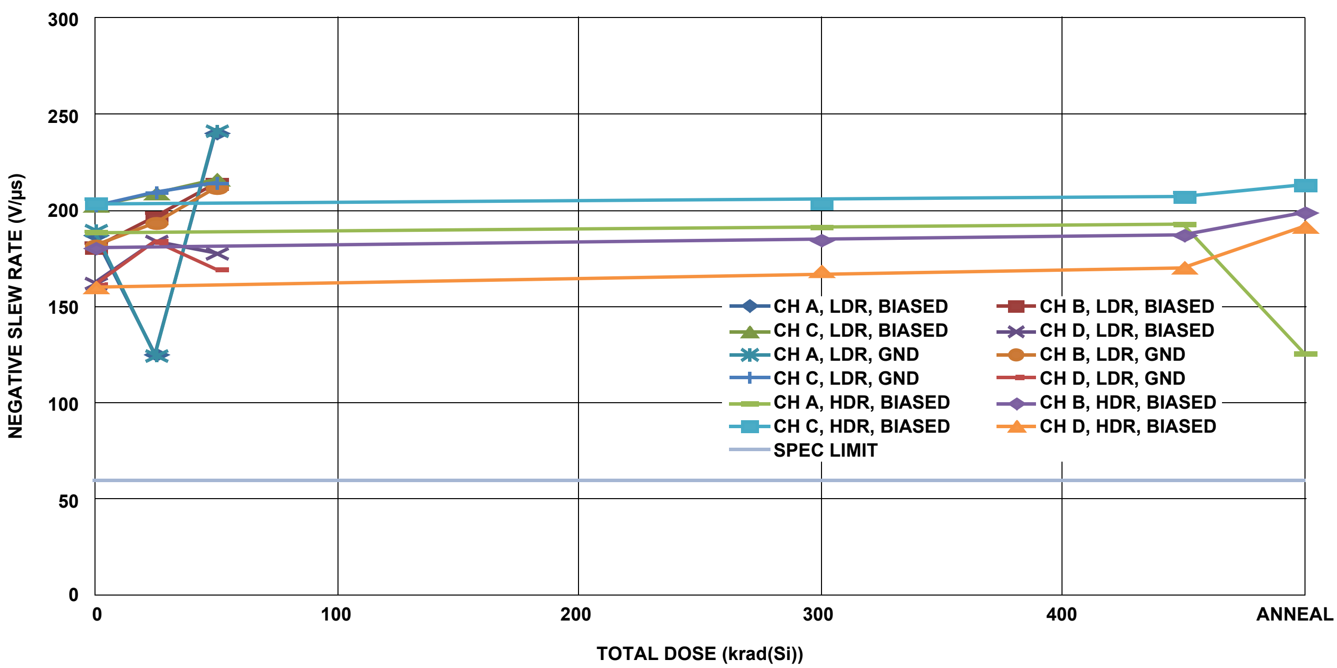


FIGURE 16. **ISL70444SEH** negative slew rate, channels A through D, as a function of total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 2) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 69.7rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal. The sample size for the two low dose rate cells and the high dose rate cell was 5 for each cell. The specification limit is 60V/µs minimum.

Discussion and Conclusion

This document reports the results of low and high dose rate testing of the ISL70444SEH quad operational amplifier. Parts were irradiated under bias and with all pins grounded at low dose rate and under bias at high dose rate per MIL-STD-883 Test Method 1019.7, at 0.01rad(Si)/s and 50rad(Si)/s respectively. The low dose rate test was run to 50krad(Si) and the high dose rate was run to 300krad(Si), with the high dose rate samples subjected to a high temperature anneal under bias at 100°C for 168 hours. All parameters remained within the SMD and data sheet post-irradiation limits at all downpoints. The part has a large number of measured parameters, so we have summarized the results in a table of attributes data (5.1) followed by a limited number of curves of interest (5.2). We will discuss each of the figures separately.

Figure 3, power supply current: This plot shows both the positive and negative power supply current and plots the aggregate supply current for all four amplifiers, which is hard to avoid since all four channels have common VCC and VEE pins. Both parameters showed excellent stability, with the average supply current per amplifier about 1.25mA. The anneal showed little effect.

Figure 4, input offset voltage: As in other PR40 operational amplifiers tested previously, this parameter is remarkably stable over irradiation and anneal, with no discernible bias or dose rate sensitivity.

Figures 5 and 6, positive and negative input bias current: This parameter is the common indicator of low dose rate sensitivity. Figures 5 and 6 show the response, and we note that the parameters were stable at all downpoints. The high temperature anneal showed little effect. As the data at all downpoints was well within the pre-irradiation datasheet specifications the part is not considered low dose rate sensitive.

Figure 7, input offset current: This parameter was stable at all downpoints including the anneal.

Figure 8 and 9, output high and low voltage: The names of these parameters are perhaps a little misleading, as they are commonly used for digital parts but have a quite different meaning in an analog context. The high or low output voltage is a measure of how close the output can swing to the respective power supply rail, which are +18V and -18V for this plot. Both parameters were stable at all downpoints including the anneal.

Figure 10 and 11, positive and negative open loop gain: Both parameters were stable at all downpoints including the anneal.

Figure 12 and 13, positive and negative power supply rejection ratio: Both parameters were stable at all downpoints including the anneal, with a very slight increase of the positive power supply rejection ratio over anneal. The negative power supply rejection ratio for Channel B showed some variation, which is considered indicative of ATE repeatability issues.

Figure 14, common mode rejection ratio: The parameter showed some variation for Channels A, C and D for the high dose rate work, which is again considered indicative of ATE repeatability issues, but was overall stable.

Figure 15 and 16, positive slew rate: Both parameters showed indications of ATE repeatability issues but were stable overall. The positive slew rate showed variation in both directions over the high temperature anneal, and this response is considered artifactual.

Given the excellent performance shown in these plots, and in particular the stability shown by the key input bias current parameter, the part is not considered dose rate sensitive. The part is acceptance tested on a wafer by wafer basis to 300krad(Si) at high dose rate (50 – 300rad(Si)/s) and to 50krad(Si) at low dose rate (0.01rad(Si)/s), insuring hardness to the specified level for both dose rates. No significant differences in total dose response were noted between biased and grounded irradiation for any parameters. Additionally, no channel to channel differences were noted, either in the pre-irradiation data or in the total dose response of the parts.

Appendices

TABLE 2. REPORTED PARAMETERS AND THEIR POST-IRRADIATION LIMITS

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNITS	NOTES
3	Positive power supply current	-	9.6	mA	Sum of all 4 channels
3	Negative power supply current	-	-9.6	mA	Sum of all 4 channels
4	Input offset voltage	-400	+400	µV	Channels A through D
5	Positive input bias current	-370	+370	nA	Channels A through D
6	Negative input bias current	-370	+370	nA	Channels A through D
7	Input offset current	-17	+17	nA	Channels A through D
8	Output high voltage	-	160	mV	Channels A through D
9	Output low voltage	-	160	mV	Channels A through D
10	Positive open loop gain	97	-	dB	Channels A through D
11	Negative open loop gain	97	-	dB	Channels A through D
12	Positive power supply rejection ratio	90	-	dB	Channels A through D
13	Negative power supply rejection ratio	90	-	dB	Channels A through D
14	Common mode rejection ratio	70	-	dB	Channels A through D
15	Positive slew rate	60		V/µs	Channels A through D
16	Negative slew rate	60		V/µs	Channels A through D

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