Radiation Report

OPA4H014-SEP Neutron Displacement Damage (NDD) Characterization

ABSTRACT

The OPA4H014-SEP was subjected to a one-time characterization to determine the effects of Neutron Displacement Damage (NDD) to the device parameters. A sample size of nine units was exposed to radiation testing per MIL-STD-883 (Method 1017 for Neutron Irradiation). The samples were dosed to exposure levels of 1×10^{12} n/cm^2, 5×10^{12} n/cm^2, and 1×10^{13} n/cm^2, with three samples evaluated per exposure level. Electrical testing was performed at Texas Instruments before and after neutron irradiation using the production test program for the device. Degradation of offset voltage, input bias current, input offset current, and open-loop gain specifications on some samples was observed and is discussed herein.

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1 Overview

The OPA4H014-SEP is a low-power JFET input operation amplifier (op amp) that features good drift and low input bias current. With an input range that includes V– and a rail-to-rail output, designers can take advantage of the low-noise characteristics of JFET amplifiers while interfacing to single-supply, precision analog-to-digital converters (ADCs) and digital-to-analog converters (DACs).

Table 1-1 lists general device information and NDD testing conditions.

Table 1-1. Overview Information

TI Part Number	OPA4H014-SEP
VID Number	V62/21607
Device Function	Radiation Tolerant 11-MHz, Precision, Low-Noise, RRO, JFET Amp
Technology	BICOM-3XHV
Device Package	14-pin TSSOP (PW)
Unbiased Quantity Tested	9
Exposure Facility	VPT Rad, Chelmsford, MA
Neutron Fluence (1-MeV Equivalent)	1.0×10^{12}, 5.0×10^{12}, 1.0×10^{13} n/cm^2
Irradiation Temperature	25°C
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2 Test Procedures

The OPA4H014-SEP samples was electrically pre-tested using the production automated test equipment program. General test procedures were as per MIL-STD-883, Method 1017.

Table 2-1. Neutron Irradiation Conditions

Serial Numbers	Sample Qty	Neutron Fluence (n/cm^2)	Bias
1, 2, 3	3	1.0×10^{12}	Unbiased
4, 5, 6	3	5.0×10^{12}	Unbiased
7, 8, 9	3	1.0×10^{13}	Unbiased

Table 2-2. OPA4H014-SEP Specification Compliance Matrix

Parameter	Test Condition	OPA4H014-SEP Data Sheet (SBOSA94)				Test #
		MIN	TYP	MAX	Unit	
Input offset voltage			±30	±120	µV	500.0-503.0, 710.0-713.0, 730.0-733.0
	V_S = ±9 V			±220		1100.0-1103.0, 1900.0-1903.0, 2100.0-2103.0, 2310.0-2313.0, 2330.0-2333.0, 2510.0-2513.0, 2530.0-2533.0, 3110.0-3113.0
Power-supply rejection ratio			±0.1	±0.5	µV/V	3700.0-3703.0
Input bias current			±0.5	±10	pA	1300.0-1303.0, 1500.0-1503.0
Input offset current			±0.5	±10		1700.0-1703.0
Common-mode rejection ratio	V_S = ±9 V, (V–) – 0.1 V < V_{CM} < (V+) – 3.5 V	126	140		dB	3900.0-3903.0
Open-loop voltage gain	(V–) + 0.35 V < V_{OUT} < (V+) – 0.35 V, R_L = 10 kΩ	120	126		dB	2540.0-2543.0
	(V–) + 0.35 V < V_{OUT} < (V+) – 0.35 V, R_L = 2 kΩ	114	126			740.0-743.0, 2340.0-2343.0
Gain bandwidth			11		MHz	2900.0-2903.0
Slew rate			20		V/µs	2700.0-2703.0, 2710.0-2713.0
Voltage output swing from rail	R_L = 10 kΩ, A_{OL} ≥ 108 dB		(V–) + 0.2	(V–) + 0.2	V	2500.0-2503.0, 2520.0-2523.0
	R_L = 2 kΩ, A_{OL} ≥ 108 dB		(V+) – 0.35	(V+) – 0.35		700.0-703.0, 720.0-723.0, 2300.0-2303.0, 2320.0-2323.0
Short-circuit current	Source		36		mA	3300.0-3303.0
	Sink		–30			3500.0-3503.0
Quiescent current (per amplifier)	I_O = 0 A		1.8	2	mA	300.0-300.1, 900.0-900.1, 4100.0-4100.1, 4500.0, 4500.1

3 Facility

VPT Rad performed neutron displacement damage irradiations in a low-enriched, open-pool, water moderated, thermal neutron reactor at the University of Massachusetts Lowell. The reactor uses flat-plate type fuel and has a maximum thermal energy output of up to 1 MW. The Fast Neutron Irradiator (FNI) faces one side of the reactor core. The experimental facility replaces three beam ports that originally existed on the left side of the research reactor. The FNI is designed to give a fast flux level ≥ 10^{11} n/cm^2–s, with relatively low thermal fluence and gamma dose rates. Samples with a cross-sectional area as large as 30 cm (12 in) × 30 cm (12 in) and up to 15 cm (6 in) thick can be irradiated. The fast neutron flux is designed to be nearly uniform over the 30 cm (12 in) × 30 cm (12 in) area facing the core, and the fast fluence variation through the sample thickness is minimized through a single 180° rotation of the sample canister at the midpoint of the irradiation period. The fluences are calculated based on 1-MeV equivalences.

The neutron fluence rate is determined using the previously-measured neutron radiation field for the FNI, performed in accordance with ASTM standards (ASTM F1190), and correlated to the measured reactor power level. The neutron dose is timed to meet the fluence specified for the irradiation. Neutron dosimetry meeting ASTM standards (ASTM E265) is used to track and make sure that irradiations meet the required minimum. The facility retains source design with the Defense Logistics Agency (DLA) Laboratory Suitability Program for ASTM Test Method 1017.

4 Results

There were no functional failures at any irradiation level. Parametric drift to levels outside the data sheet specifications was observed on all devices for the input bias current (and related input offset current) parameter, and on all but one device for the input offset voltage. Some devices experienced parametric drift for open-loop gain. All other tested parameters were observed to be within the test limits of the ATE program for the device, and as a result, within the data sheet specifications.

4.1 Input Bias Current Parametric Shift

Input bias current (I_B) for the OPA4H014-SEP is specified as ±0.5 pA typical and ±10 pA maximum at T_A = 25°C. The input bias current was measured at V_S = ±9 V, with test limits of ±6 pA for guardbanding purposes.

All of the devices exposed to neutron irradiation were found to have a measured input bias current outside of the specified data sheet limits, for both the inverting and noninverting input terminals and across all four device amplifier channels.

- Of the three samples tested to 1 × 10^{12} n/cm^2, a mean post-irradiation I_B value of 12.80 pA and maximum post-irradiation I_B value of 14.24 pA were recorded for the inverting inputs. A mean post-irradiation I_B value of 16.07 pA and maximum post-irradiation I_B value of 17.79 pA were recorded for the noninverting inputs.
- Of the three samples tested to 5 × 10^{12} n/cm^2, a mean post-irradiation I_B value of 73.24 pA and maximum post-irradiation I_B value of 74.87 pA were recorded for the inverting inputs. A mean post-irradiation I_B value of 90.04 pA and maximum post-irradiation I_B value of 91.92 pA were recorded for the noninverting inputs.
- Of the three samples tested to 1 × 10^{13} n/cm^2, a mean post-irradiation I_B value of 145.54 pA and maximum post-irradiation I_B value of 162.34 pA were recorded for the inverting inputs. A mean post-irradiation I_B value of 177.73 pA and maximum post-irradiation I_B value of 198.79 pA were recorded for the noninverting inputs.

Input offset current (I_{OS}) was found to remain within the data sheet specifications for the devices tested to 1 × 10^{12} n/cm^2, which suggests that the neutron displacement damage mechanism can affect both the inverting and noninverting inputs in a comparable manner. For samples dosed to 5 × 10^{12} n/cm^2 and 1 × 10^{13} n/cm^2, while offset current exceeded the data sheet limits, the offset current remained within approximately 10% of the mean measured input bias current.

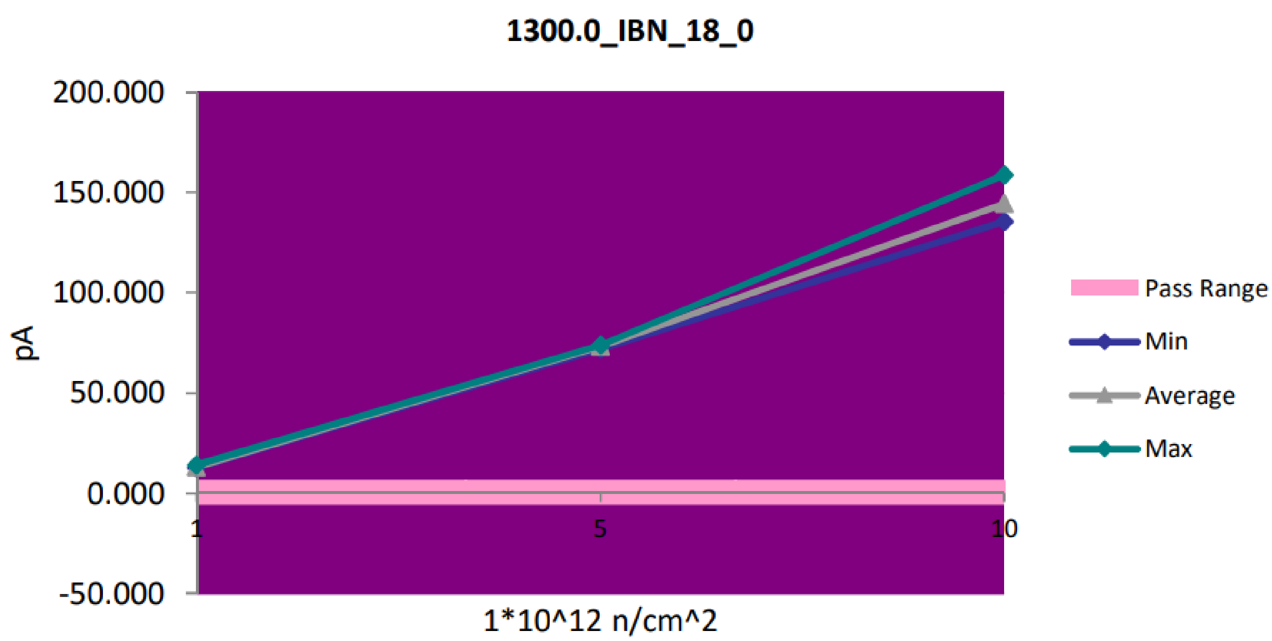

Figure 4-1. Sample Inverting Input Bias Current NDD Graph

4.2 Input Offset Voltage Parametric Shift

Input offset voltage (V_{OS}) for the OPA4H014-SEP is specified as ±30 μV typical and ±120 μV maximum at T_A = 25°C. The input offset voltage was measured at multiple supply voltages, with test limits of ±100 μV for guardbanding purposes.

All but one of the devices exposed to neutron irradiation were found to have a measured input offset voltage outside of the specified data sheet limits, across all four device amplifier channels, for at least one of the V_{OS} tests performed on the ATE. Values reported below are from one example test with V_S = ±9 V (test numbers 1100.0-1103.0). Full data for all ATE tests performed are included in the report appendix.

- Of the three samples tested to 1 × 10^{12} n/cm^2, a mean post-irradiation V_{OS} magnitude of 68 μV and maximum post-irradiation V_{OS} magnitude of 152.94 μV were recorded. Only the sample with serial number 1 did not exhibit a parametric shift to a level in excess of the data sheet specification on any channel.
- Of the three samples tested to 5 × 10^{12} n/cm^2, a mean post-irradiation V_{OS} magnitude of 110.67 μV and maximum post-irradiation V_{OS} magnitude of 284.55 μV were recorded.
- Of the three samples tested to 1 × 10^{13} n/cm^2, a mean post-irradiation V_{OS} magnitude of 186.82 μV and maximum post-irradiation V_{OS} magnitude of 508.11 μV were recorded.

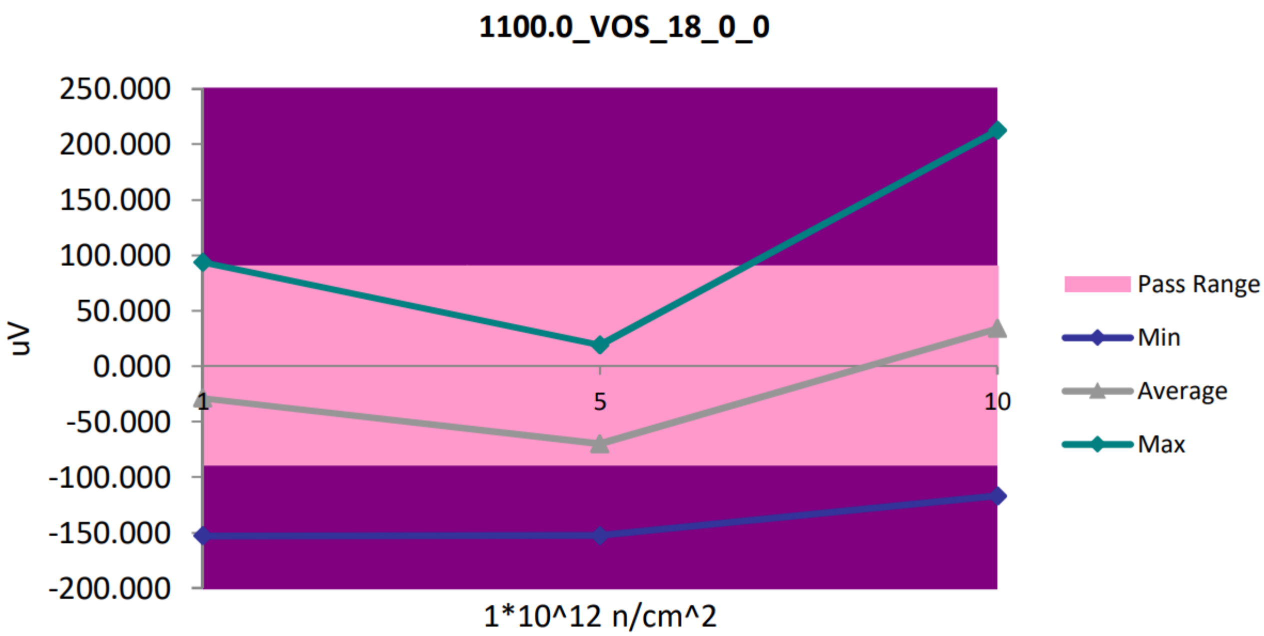

Figure 4-2. Sample Input Offset Voltage NDD Graph

4.3 Other Parametric Shifts

Power-supply rejection ratio (PSRR) for the OPA4H014-SEP is specified as ±0.1 μV/V typical and ±0.5 μV/V minimum across the recommended operating temperature (T_A = –55°C to +125°C). Power-supply rejection ratio was measured at V_S = ±9 V, with test limits of ±0.37 μV/V for guardbanding purposes. One device sample, tested to 1 × 10^{13} n/cm^2, was found to have a post-irradiation PSRR value of –0.373 μV/V, in excess of the test limit but nonetheless within the actual data sheet specification.

Open-loop gain (A_{OL}) for the OPA4H014-SEP is specified as 126 dB (±0.5 μV/V) typical and 114 dB (±2 μV/V) maximum at T_A = 25°C and with R_L = 2 kΩ. Open-loop gain was measured at V_S = ±2.25 V, with test limits of ±1.8 μV/V for guardbanding purposes. One device sample, tested to 5 × 10^{12} n/cm^2, was found to have a post-irradiation A_{OL} value of 2.411 μV/V for one channel, in excess of the data sheet specification. The A_{OL} of the other three channels remained within the data sheet specifications and test limits. Another device sample, tested to 1 × 10^{13} n/cm^2, was found to have a post-irradiation A_{OL} value of 2.483 μV/V for one channel and 2.357 μV/V for another, in excess of the data sheet specification. The A_{OL} of the other two channels of the sample remained within the data sheet specifications, with values of 1.292 μV/V and 1.951 μV/V. A_{OL} remained within the data sheet specifications and test limits for all devices when measured at V_S = ±9 V. Full data for all ATE tests performed are included in the report appendix.

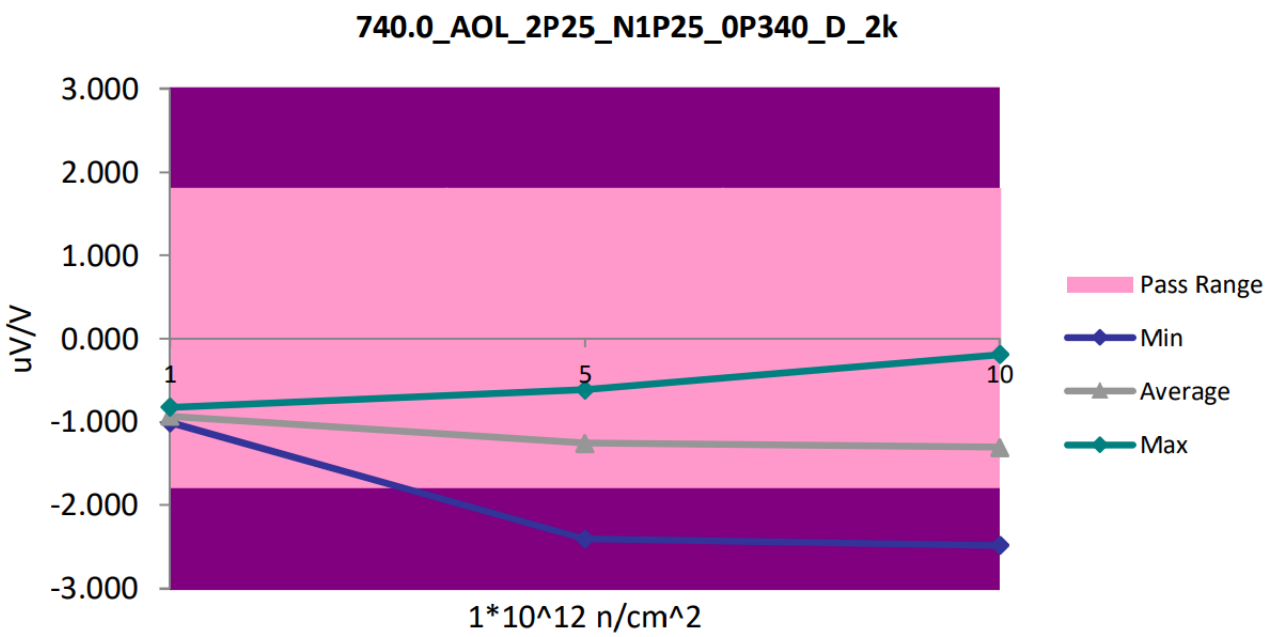

Figure 4-3. Sample Open-Loop Gain NDD Graph

5 Summary of Results

While there were no functional failures at any irradiation level, degradation of parameters was readily apparent for the device when exposed to neutron irradiation. This degradation significantly worsened as the dosage increased beyond 1 × 10^{12} n/cm^2. The specifications most significantly affected were the input offset voltage and input bias current (and related input offset current). Some devices experienced parametric drift to levels in excess of the data sheet specifications for open-loop gain (at and above 5 × 10^{12} n/cm^2). The data suggest that circuit designers seeking to use the OPA4H014-SEP must consider the possible effects of parametric drift of the I_B, I_{OS}, V_{OS}, and A_{OL} specifications when assessing circuits for fault-planning purposes.

A Test Results

This appendix contains the detailed test results.

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