Table of Contents – Analog

National Semiconductor will not guarantee the RHA performance of any product unless National Semiconductor has tested and certified the specific manufacturing lot.

Analog test reports are available on National Semiconductor's web site at www.national.com/mil.

Glossary of Analog-Specific Terms

Bandwidth: That frequency at which the voltage gain is reduced to 1/(square root of 2) times the low frequency value.

Calibrated Temperature Error: The error between operating output voltage and case temperature at 10 mV/°K over a temperature range at a specified operating current with the +25°C error adjusted to zero.

Common-Mode Rejection Ratio: The ratio of the input common-mode voltage range to the peak-to-peak change in input offset voltage over this range.

Current-Limit Sense Voltage: The voltage across the current limit terminals required to cause the regulator to current-limit with a short circuited output. This voltage is used to determine the value of the external current-limit resistor when external booster transistors are used.

Dropout Voltage: The input-output voltage differential at which the circuit ceases to regulate against further reductions in input voltage.

Feedback Sense Voltage: The voltage, referred to ground, on the feedback terminal of the regulator while it is operating in regulation.

Harmonic Distortion: That percentage of harmonic distortion being defined as one-hundred times the ratio of the root-mean-square (rms) sum of the harmonics to the fundamental. The percentage of harmonic distortion =

$$\frac{(V2^2 + V3^2 + V4^2 + \ldots)^{1/2}\,(100\%)}{V1}$$

where V1 is the rms amplitude of the fundamental and V2, V3, V4, . . . are the rms amplitudes of the individual harmonics.

Input Bias Current: The average of the two input currents

Input Common-Mode Voltage Range: The range of voltages on the input terminals for which the amplifier is operational. Note that the specifications are not guaranteed over the full common-mode voltage range unless specifically stated.

Input Impedance: The ratio of input voltage to input current under the stated conditions for source resistance (R_S) and load resistance (R_L).

Input Offset Current: The difference in the currents into the two input terminals when the output is at zero.

Input Offset Voltage: That voltage which must be applied between theinput terminals through two equal resistances to obtain zero output voltage.

Input-Output Differential: The voltage difference between the unregulated input voltage and the regulated output voltage for which the regulator will operate.

Input Resistance: The ratio of the change in input voltage to the change in input current on either input with the other grounded.

Input Voltage: The DC voltage applied to the input terminals with respect to ground.

Large-Signal Voltage Gain: The ratio of the output voltage swing to the change in input voltage required to drive the output from zero to this voltage.

Line Regulation: The change in output voltage for a change in the input voltage. The measurement is made under conditions of low dissipation or by using pulse techniques such that the average chip temperature is not significantly affected.

Load Regulation: The change in output voltage for a change in load current at constant chip temperature.

Logic Threshold Voltage: The voltage at the output of the comparator at which the loading logic circuitry changes its digital state.

Long-Term Stability: Output voltage stability under accelerated life-test conditions at +125°C with maximum rated voltages and power dissipation for 1000 hours.

Maximum Power Dissipation: The maximum total device dissipation for which the regulator will operate within specifications.

Negative Output Level: The negative DC output voltage with the comparator saturated by a differential input equal to or greater than a specified voltage.

Operating Output Voltage: The voltage appearing across the positive and negative terminals of the device at specified conditions of operating temperature and current.

Output Impedance: The ratio of output voltage to output current under the stated conditions for source resistance (R_S) and load resistance (R_L).

Output-Input Voltage Differential: The voltage difference between the unregulated input voltage and the regulated output voltage for which the regulator will operate within specifications.

Output Leakage Current: The current into the output terminal with the output voltage within a given range and the input drive equal to or greater than a given value.

Output Noise Voltage: The RMS AC voltage at the output with constant load and no input ripple, measured over a specified frequency range.

Output Resistance: The small signal resistance seen at the output with the output voltage near zero.

Output Sink Current: The maximum negative current that can be delivered by the comparator.

Output Voltage Range: The range of regulated output voltages over which the specifications apply.

Output Voltage Scale Factor: The output voltage obtained for a unit value of resistance between the adjustment terminal and ground.

Output Voltage Swing: The peak output voltage swing, referred to zero, that can be obtained without clipping.

Output Voltage Temperature Drift: The average drift rate of offset voltage for a thermal variation from room temperature to the indicated temperature extreme.

Positive Output Level: The high output voltage level with a given load and the input drive equal to or greater than a specified value.

Power Consumption: The power required to operate the comparator with no output load. The power will vary with signal level, but is specified as a maximum for the entire range of input signal conditions.

Power Supply Rejection: The ratio of the change in input offset voltage to the change in power supply voltages producing it.

Quiescent Current: That part of the positive input current that does not contribute to the positive load current. The regulator ground lead current.

Response Time: The interval between the application of an input step function and the time when the output crosses the logic threshold voltage. The input step drives the comparator from some initial, saturated input voltage to an input level just barely in excess of that required to bring the output from saturation to the logic threshold voltage. This excess is referred to as the voltage overdrive.

Ripple Rejection: The line regulation for AC input signals at or above a given frequency with a specified value of bypass capacitor on the reference bypass terminal.

Saturation Voltage: The low-output voltage level with the input drive equal to or greater than a specified value.

Settling Time: The time between the initiation of the input step function and the time when the output voltage has settled to within a specified error band of the final output voltage.

Slew Rate: The internally-limited rate of change in output voltage with a large-amplitude step function applied to the input.

Standby Current Drain: That part of the operating current of the regulator which does not contribute to the load current *(see Quiescent Current)*.

Strobe Current: The current out of the strobe terminal when it is at the zero logic level.

Strobe Output Level: The DC output voltage, independent of input conditions, with the voltage on the strobe terminal equal to or less than the specified low state.

Strobe "ON" Voltage: The maximum voltage on either strobe terminal required to force the output to the specified high state independent of the input voltage.

Strobe "OFF" Voltage: The minimum voltage on the strobe terminal that will guarantee that it does not interfere with the operation of the comparator.

Strobe Release Time: The time required for the output to rise to the logic threshold voltage after the strobe terminal has been driven from zero to the one logic level.

Supply Current: The current required from the positive or negative supply to operate the operational amplifier or comparator with no output load. The power will vary with input voltage, but is specified as a maximum for the entire range of input voltage conditions.

Temperature Stability: The percentage change in output voltage for a thermal variation from room temperature to either temperature extreme.

Temperature Stability of V_O: The percentage change in output voltage for a thermal variation from room temperature to either temperature extreme.

Thermal Regulation: Percentage change in output voltage for a given change in power dissipation over a specified time period.

Transient Response: The closed-loop step-function response of the amplifier under small-signal conditions.

Uncalibrated Temperature Error: The error between the operating output voltage at 10 mV/°K and case temperature at specified conditions of current and case temperature.

Unity Gain Bandwidth: The frequency range from DC to the frequency where the amplifier open loop gain rolls off to one.

Voltage Gain: The ratio of the change in output voltage to the change in voltage between the input terminals producing it and under the stated conditions for source resistance (R_S) and load resistance (R_L).

Radiation Results – Analog Summary

National Semiconductor's large portfolio of linear product includes several technologies (i.e., CMOS, Bipolar, and BiCMOS) and numerous radiation responses. At this time, linear products are being RHA qualified to radiation levels up to 100 krad(Si). Two RHA options are available for National's linear radiation-resistant products:

- **Option #1: Radiation Lot Acceptance Test (RLAT)** Addresses the condition where the customer's requested total dose level is within established Radiation Hardness Assured (RHA) capability limits. Pass/fail criteria is assigned to post-irradiation electrical tests.
- **Option #2: Radiation Characterization Testing** Addresses customer's request for a total ionizing dose level on a particular linear product that either exceeds its radiation capabilities or has never been characterized for its radiation-tolerance level. Pass/fail criteria is assigned to the post-irradiation electrical tests.

All linear product radiation testing is performed per MIL-STD-883E, Method 1019.5, Condition A [High Dose Rate: 50 - 300 rad(Si)/s] unless otherwise specified. National Semiconductor's linear products demonstrate a range of radiation tolerance from 20 - 800 krad(Si) total dose levels, depending upon product type. Comlinear parts have radiation-resistant levels of 10 krad(Si) to 1 Mrad(Si) and are manufactured using a complementary bipolar IC process.

Operational Amplifiers

National offers a wide range of operational amplifiers, buffers, and comparators. This portfolio includes general-purpose operational amplifiers (such as the LM101A, LM108, LM124, LM148, and others) as well as application-specific op amps that address high-speed and low-power/high-precision markets. Radiation data is available on most of National's general purpose op amps, with test data showing resistance ranging from 20 to 100+ krad(Si).

Supporting the high-speed market are National's unique, VIP™ (Vertically Integrated PNP) op amps. These easy-to-use op amps have high slew rates and are ideal for high-speed applications, especially those requiring stability while driving large capacitive loads. Providing broad design flexibility, VIP op amps meet gain bandwidths from 17MHz to 725MHz. Radiation data is available on many VIP op amps, with test data showing resistance ranging from 10 krad(Si) to 800 krad(Si).

National's CMOS op amps address low power and high precision symmetrical design for ultra-low input bias current, low input offset voltage, low total supply current, and rail-to-rail input and output. Rail-to-rail capability eases design-in, allows maximum use of the full dynamic signal range, and improves system efficiency. Low input offset drift maintains the highest accuracy and most precise solution possible over the full military temperature range. National's CMOS op amps are ideal for low-power and battery-operated applications. Radiation data is available on some of National's pure CMOS op amps, with test data showing resistance ranging from 5 krad(Si) to 10 krad(Si).

Power Management

National's Power Management portfolio consists of standard regulators, low dropout regulators, switching regulators, and motor drivers that are primarily built on bipolar processes. Many of National's industry-standard fixed and adjustable regulators provide output voltages with less than 0.5V of overhead required at the input. Radiation data is available on many of National's regulators, with test data showing resistance ranging from 10 krad(Si) to 200 krad(Si).

National's easy-to-design-with switching regulators (LM2595, LM1575, and LM1577 series) provide either step-down or step-up output voltages. The latest generation of these switching regulators are more than 90% efficient, require as few as four external components, and come with easy-to-use design software. Radiation data is available on both generations of National's switching regulators. Radiation test data on the switching regulators illustrate resistance ranging from 30 krad(Si) to 200 krad(Si).

Also offered in National's Power Management portfolio is the LMD18200-2D/883, a 3A, 55V full-bridge motor driver. Radiation data on National's motor driver shows resistance ranging to 10 krad(Si).

Data Acquisition

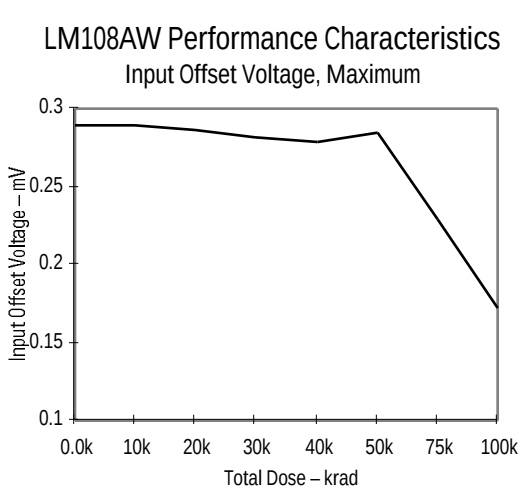
National's Data Acquisition products cover A-to-D converters, voltage references, a complete data acquisition system on a chip, and temperature sensors. The 8- and 12-bit A-to-D converters include such features as self-calibration, on-board multiplexer, and sample & hold which will operate on a single 5V supply. Radiation data on National's latest generation A/D converters is not available at this time. The most highly integrated data acquisition product available is the LM12H458 DAS, which includes a fully differential, self-calibrating, 12-bit plus sign A-to-D, on-board multiplexer, reference, sample & hold, 32-word FIFO and DMA, 8-word instruction RAM, event sequencer, Databus, and 16-bit timer. Radiation data on National's DAS chip shows resistance ranging to 10 krad(Si).

National's temperature sensor offers a high precision linear output and guaranteed accuracy. Radiation data available on precision temperature sensor show resistance ranging to 100 krad(Si).

Comlinear

For more than a decade, National's Comlinear products have focused on high-speed op amp, buffers, multiplexers, and data converter designs. This emphasis on high-speed design solutions has resulted in an unmatched capability in high-speed design and modeling. The Comlinear devices are primarily built upon an advanced complementary bipolar process which one United States government testing agency has called "*… one of the most advanced commercial linear bipolar processes…*" This process features implanted emitters and a bulk Si substrate that are specifically designed for linear applications. This process contains no lateral or substrate PNPs. In addition to high and low dose rate data, neutron data is available on select Comlinear devices.

The Comlinear product lines provide the robust, reliable assembly and high radiation tolerance required in space projects. Many Comlinear monolithic products are built to space-level requirements. All Comlinear MIL-STD-883 products are candidates for processing to National's Comlinear space flow.



LM108AW Performance Characteristics

Input Offset Voltage - mV (V+ = +5V, V- = -35V, VCM = 15V

Limits: -.5mV (SG1), -1.0mV - 1.0mV (SG2)

Dose	Average	Minimum	Maximum	S. Dev.	Fail[1]
0.0	0.061	-0.144	0.289	0.148	0
10	0.057	-0.149	0.289	0.149	0
20	0.059	-0.138	0.286	0.146	0
30	0.054	-0.145	0.282	0.147	0
40	0.050	-0.155	0.279	0.148	0
50	0.052	-0.160	0.285	0.151	0
75	0.000	-0.214	0.230	0.150	0
100	-0.065	-0.298	0.172	0.157	0

Note 1: Number of devices that were outside sub group 1 limits

Phased Locked Loops (PLL)

Newly completed radiation testing has been performed on several versions of National Semiconductor's low power, high frequency Phase Locked Loop (PLL) frequency synthesizers. *(See table on right)*. PLL products are fabricated on National's ABiC IV 0.8µm BiCMOS process. This epi process contains no lateral or substrate PNP devices. The part types that were investigated for radiation-hardness capability were the LMX2305, LMX2315, and LMX2325. Data indicates that all part types typically function up to 50 krad(Si) total dose. Depending upon the particular part type and dose rate, electrical parameters remain within pre-radiation limits between 15 krad(Si) and 30 krad(Si) total ionizing dose levels. Additional total dose testing will be done before final post-irradiation parametric limits (PIPL) and radiation-hardness assurance capability limits (RHACL) are assigned.

Single event effects testing and proton testing have been performed by government and other outside agencies. These testings show there is no sensitivity to single event latchup to an Effective LET of 84 MeV-cm2/mg (heavy ion). Single event upset occurrences were noted and determined to be acceptable for a particular application and orbit. Sensitivity to proton testing was not evident.

Data Presentation

A Test Summary sheet provides details on the origins of test samples, dose rate, list of parameters tested, and total variation in those parameters. Details of the test consist of select device parameters plotted and tabulated as a function of total dose. Test conditions for each parameter are also specified. Acceptance limits specified in MDS (military datasheets) are plotted on the graph for reference purposes. This RHA report is supplied as a guideline to demonstrate the characteristics of National's products in a total dose radiation environment. The results reported are representative of the lot tested in this specific sample and should not be used as generic RHA qualification data. National Semiconductor uses different process flows for different product qualification levels. At each radiation exposure level, minimum and maximum shows a plausible variation in the parameter values. This is attributable to radiation exposure as well as variation between lots and between wafers. Measurement variation is presumed to be insignificant. Whenever possible, radiation test reports provide an estimate of the percentage of total variation that can be attributed to radiation exposure.

National's Family of QML PLLs

National Part #	SMD#
LMX2305WG-QML LMX2305WG-MLS	5962-9860901QXA
LMX2315WG-QML LMX2315WG -MLS	5962-985001QXA
LMX2325WG-QML LMX2325WG-MLS	5962-985002QXA
LMX2326WG-QML LMX2326WG-MLS	5962-9861001QXA

Note: Radiation test reports for National Semiconductor's Linear/Analog products are available on the web at www.national.com/mil.

Analog Products – Test Results

Linear Products

	Total Ionizing Dose Results		Single Event Latchup		
Device	Total Dose to Pre-Rad Limits (krad)	Functional Level (krad)	SEL	LET (MeV/mg/cm^2)	Process Technology
LF156	10	> 15			Bi-FET
LM35AH	100	> 100			Bipolar-SiCr
LM101	80 - 100	> 100			Bipolar
LM105	100	> 100			Bipolar
LM107	> 100	> 100			Bipolar
LM108	80 - 100	> 100			Bipolar
LM109	20 - 50	> 50			Bipolar
LM110	50	> 50			Bipolar
LM111	< 10	> 20			Bipolar
LM113	100	> 100			Bipolar
LM117H	20 - 30	> 30	No	>110	Bipolar
LM117K	30 - 40	> 50	No	>110	Bipolar
LM118	50	> 200			Bipolar
LM119	10 - 20	> 20	No	>100	Bipolar
LM120-12(H)	> 100	> 100	No	>110	Bipolar
LM120-12(K)	> 100	> 100	No	>110	Bipolar
LM120-15(H)	> 100	> 100			Bipolar
LM120-15(K)	> 100	> 100			Bipolar
LM124	> 100	> 125	No	>90	Bipolar
LM124A	25 - 30	> 25			Bipolar
LM12H458MEL	5	< 10			CMOS
LM131	< 20	> 20			Bipolar
LM135	> 50	> 50			Bipolar
LM136AH-2.5	100	> 100	No	>110	Bipolar
LM136AH-5.0	30	>100			Bipolar
LM137(H)	20 - 30	50			Bipolar
LM137(K)	20 - 30	50			Bipolar
LM139	50 - 80	> 100	No	>80	Bipolar
LM140-5(H)	20	> 20			Bipolar
LM140-121(H)	20	> 50			Bipolar
LM140-12(K)	20	> 50			Bipolar
LM140-15(H)	> 20	> 50			Bipolar
LM140-15(K)	> 20	> 50			Bipolar
LM148	> 20	> 20			Bipolar
LM158	12 - 50	> 50	No		Bipolar
LM158A	12 - 50	> 50	No		Bipolar
LM185	< 10	> 10			Bipolar
LM193	< 20	> 100	No	>110	Bipolar
LM193A	< 20	> 100	No	>110	Bipolar
LM555	> 25	> 25			Bipolar
LM614AMJ	100	> 100			Bipolar

Notes: 1. Linear products have been irradiated to High Dose rates as required by MIL-STD-883D, Method 1019.4. "Worst-case" conditions for Linear products are derived through Low Dose Rate testing.

2. Using pre-radiation limits provides small additional margin for Linear products that are used in space environments tested at high dose rate.

3. Parts qualified to RHA Level R are guaranteed to meet their post rad specifications after 100 krads(Si) total dose. Rad levels for all other products are typical and are not guaranteed.

Linear Products (cont.)

	Total Ionizing Dose Results		Single Event Latchup		
Device	Total Dose to Pre-Rad Limits (krad)	Functional Level (krad)	SEL	LET (MeV/mg/cm^2)	Process Technology
LM723	> 100	> 100			Bipolar
LM1575J-5.0	30	> 50			Bipolar
LM1575J-ADJ	30	> 50			Bipolar
LM6142AMJ	10	< 100			VIP III
LM6161	50	200			VIP I
LM6172	400	> 800			VIP III
LM7171	200	> 200			VIP III
LM2595J-5.0	100	> 100			Bipolar
LM2595J-ADJ	100	> 100			Bipolar
LM2991J	10	< 30			Bipolar
LMC6062	5	10			CMOS
LMX2305	25	50	No	>84	BiCMOS
LMX2315	25	50	No	>84	BiCMOS
LMX2325	25	50	No	>84	BiCMOS
LP2951	> 75	> 100	No	>90	Bipolar
LP2953	> 30	> 75			Bipolar
LP2956	30	< 50			Bipolar

Notes: 1. Linear products have been irradiated to High Dose rates as required by MIL-STD-883D, Method 1019.4. "Worst-case" conditions for Linear products are derived through Low Dose Rate testing.

2. Using pre-radiation limits provides small additional margin for Linear products that are used in space environments tested at high dose rate.

3. Parts qualified to RHA Level R are guaranteed to meet their post rad specifications after 100 krads(Si) total dose. Rad levels for all other products are typical and are not guaranteed.

Comlinear High-Performance Op Amps

Product within Process * tested	Neutron Irradiation (neutron/cm^2)	Total Dose	Dose Rate	Result Summary
CBIC-U (39x39 Mil Die Size) Process Type/Base Chip Technology				
CLC109 CLC110 CLC111	1x10^{12}	30, 100, 300, 1000	50 rads/sec	Slight change in DC operating point
CLC400* CLC401* CLC406 CLC412 CLC425 CLC522 CLC532	Not Available	10, 30, 50, 100	570 rads (Si)/min	No degradation of gain; slight degradation of bandwidth at initial radiation exposure
CBIC-U (54x54 Mil Die Size) Process Type/Base Chip Technology				
CLC400* CLC401* CLC402	Not Available	10,000	155 rads/sec	Slight change in DC operating point; no degradation in AC characteristics
CLC404 CLC409 CLC410	Not Available	10, 30, 100, 300, 1000	140 rads (Si)/sec	Negligible degradation to 1000 krads specification; should meet specification to 3000 krads
CLC420 CLC422 CLC500	1.85x10^{14}	None	None	Little change in the small signal frequency response over a wide gain range
CLC501* CLC502 CLC505	Not Available	5, 10, 15, 20, 25	500 rads/hour	No degradation of gain; slight degradation of bandwidth at initial radiation exposure
CLC520*	6x10^{11}	30, 60, 100, 150, 200	50 rads/sec	Change in DC bias characteristics; no AC testing performed
	1x10^{12}	30, 100, 300, 1000	50 rads/sec	Slight change in DC operating point
CBIC-U (54x68 Mil Die Size) Process Type/Base Chip Technology				
CLC114				
CLC115				
CBIC-U (76x65 Mil Die Size) Process Type/Base Chip Technology				
CLC411 CLC414 CLC415* CLC533	Not Available	30, 100, 300, 1000		

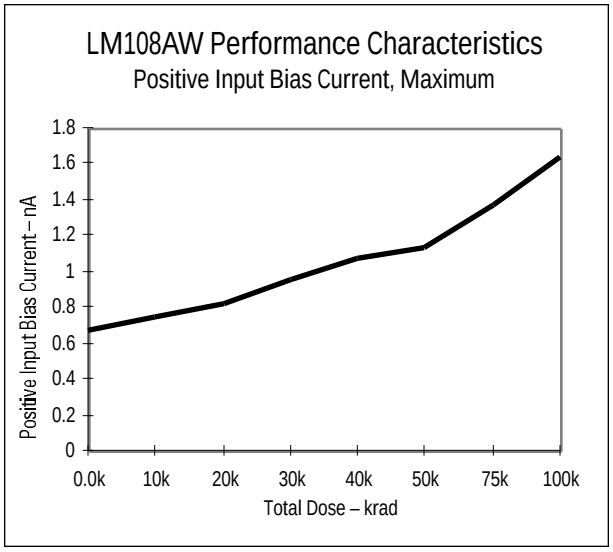
Note: Parts qualified to RHA Level R are guaranteed to meet their post rad specifications after 100 krads(Si) total dose. Rad levels for all other products are typical and are not guaranteed.

Comlinear High-Performance Op Amps (cont.)

Product within Process * tested	Neutron Irradiation (neutron/cm^2)	Total Dose	Dose Rate	Result Summary
CBIC-U2 (40x59 Mil Die Size) Process Type/Base Chip Technology				
CLC405				
CLC407				
CLC408				
CLC418				
CLC426				
CLC428				
CBIC-U2 (84x38 Mil Die Size) Process Type/Base Chip Technology				
CLC427				
CBIC-V2 (44x44 Mil Die Size) Process Type/Base Chip Technology				
CLC440	Report Available	10,000		
CLC446				
CLC449				
Generic CBIC-V*				
CBIC-R (58x68 Mil Die Size) Process Type/Base Chip Technology				
CLC430	Report Available	10,000	155 rads/sec	Change in outset voltage and bias current; moderate change in transimpedance.
CBIC-R (84x86 Mil Die Size) Process Type/Base Chip Technology				
CLC431				
CLC432				

Note: Parts qualified to RHA Level R are guaranteed to meet their post rad specifications after 100 krads(Si) total dose. Rad levels for all other products are typical and are not guaranteed.

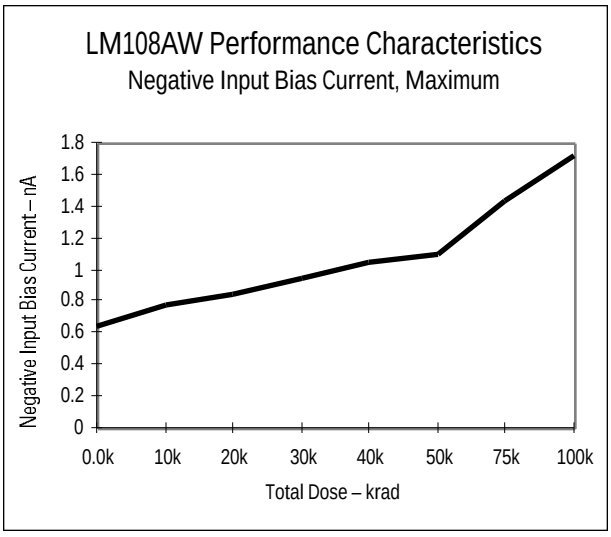
Analog Final Reports



Test Report Example

Includes:

- Test names from National Semiconductor datasheet or Customer Drawing
- Product information
- Statistical summary
- Test pass/fail status
- Graphic summary



Report Statistics Example

Includes:

- Test names from National Semiconductor's datasheet or Customer Drawing
- Summarized test results by exposure level
- Test limits from test program
- Statistical values

LM108AW Performance Characteristics
Positive Input Bias Current - nA
Limits: -.1nA, -.2nA (SG1), -1.0nA, - 3.0nA (SG3)

Dose	Average	Minimum	Maximum	S. Dev.	Fail[1]
0.0	0.613	0.546	0.671	0.052	0
10	0.659	0.584	0.738	0.060	0
20	0.737	0.653	0.822	0.063	0
30	0.838	0.754	0.950	0.076	0
40	0.923	0.821	1.064	0.089	0
50	1.023	0.916	1.132	0.086	0
75	1.236	1.107	1.374	0.106	0
100	1.471	1.324	1.632	0.124	0

Note 1: Number of devices that were outside sub group 1 limits

LM108AW Performance Characteristics
Negative Input Bias Current - nA
Limits: -.1nA, -.2nA (SG1), -1.0nA, - 3.0nA (SG3)

Dose	Average	Minimum	Maximum	S. Dev.	Fail[1]
0.0	0.567	0.440	0.644	0.075	0
10	0.671	0.584	0.766	0.067	0
20	0.762	0.682	0.848	0.069	0
30	0.833	0.720	0.938	0.086	0
40	0.931	0.801	1.044	0.093	0
50	1.012	0.895	1.099	0.076	0
75	1.271	1.133	1.431	0.104	0
100	1.514	1.338	1.712	0.130	0

Note 1: Number of devices that were outside sub group 1 limits

Analog test reports are available on National Semiconductor's web site at www.national.com/mil/.