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# Radiation Testing

### Test Philosophy

National's Mil/Aero group offers a solution to reduce extensive shielding measures while maintaining cost effectiveness. By testing inherently radiation-resistant standard devices, National provides products that offer:

- QML-V or Q testing, or custom testing as outlined in customer SCDs (Source Control Drawings)
- Guaranteed specifications for reliable radiation designs
- Cost effectiveness
- Timely delivery

Through this Mil/Aero Radiation Program, products are fully qualified with respect to different radiation environments. Complete total dose radiation data is supplied with each customer order.

National recognizes that radiation resistance needs differ within tactical and space environments. Our radiation testing program is flexible to individually address your radiation and processing needs. Process flows include QML-V and Q, Standard Military Drawings (SMDs), MIL-STD-883, and SCDs to Levels S and B.

### National's Radiation Effects Laboratories

National Semiconductor operates radiation effects laboratories (REL) in South Portland, Maine; and Santa Clara, California.

### All About National's South Portland, Maine, REL

#### Certification – Maine

- Dose rate of the Gammacell is certified by the use of National Institute of Standards and Technology (NIST) ionizing dose dosimetry.
- Licensed by the Nuclear Regulatory Commission (NRC) to handle neutron-irradiated material. This capability permits testing product for both total dose and neutron irradiation. National currently contracts Sandia National Labs and White Sands Missile Range to perform Neutron irradiation tests.
- Certified by the Defense Supply Center, Columbus, Ohio (DSCC) for Total Dose Lab Suitability. This signifies that the REL meets all government requirements to perform total dose testing.
- Lab Suitability certification denotes that testing performed at National's South Portland REL facility and the data generated are fully recognized and acceptable by all government agencies, their contractors, and subcontractors. This qualifies the South Portland REL to support QML-V RHA programs for FACT product, for production radiation qualification of all of National's product lines, and for any customer-requested testing that requires total dose data from a DSCC-certified laboratory.

National's Gammacell in South Portland, Maine

- REL research includes evaluation of National's analog, interface, logic, and memory families as well as other products requested by customers.

#### Test Methodology – Maine

Under National's test methodology, sample devices are tested to establish the peak radiation operating levels of each function. While "pass/fail" or attribute testing is important, National's Mil/Aero South Portland REL endorses parametric or variable testing. These test results are based on step-stress irradiation responses.

National's wafer radiation testing provides consistent device radiation tolerance performance. Wafer testing eliminates significant variability from lot-to-lot or

wafer-to-wafer. All devices have complete lot and wafer traceability, and each device is guaranteed to be compliant with your SCD. In fact, typical test results exceed the minimum requirements specified in customers' SCDs.

Comprehensive data reduction and statistical analysis is performed and provided with each order, including electrical performance based on device test results and radiation testing with compliance with Level V and Level Q process flows. National also offers customers an opportunity to review test results prior to accepting products from any particular wafer.

Offering the best partnership relationship possible, we work with you to ensure that all testing completely suits your needs.

**The Step-by-Step Process – Maine**

1. All wafers are fabricated according to S-Level or equivalent specifications. This includes SEM (Scanning Electron Microscope) inspection of two metalization steps and wafer lot acceptance data.
2. Each wafer selected for radiation testing is classified as a "wafer lot" and is stored in a wafer bank for radiation-hardened product.
3. Total Dose testing is performed at room temperature (+25˚C) in full accordance with MIL-STD-883E, Method 1019.5.
4. The twelve (minimum per wafer) radiation test die subjected to testing are chosen just beyond the RHA area. This area is defined as that part of the wafer enclosed by 2/3 of the wafer's radial dimension as drawn from the center toward the wafer edge. Die within this area are used if the customer invokes this QML requirement.
5. Sample die are assembled and tested to full QML or customer specifications prior to radiation testing.
6. Every product type is qualified under worst-case bias conditions for Total Dose radiation response on a step-stress irradiation basis, e.g., at radiation interval levels of 3 krad(Si), 10 krad(Si), etc., up to 100 krad(Si) or to functional failure.
7. Radiation characterization includes determining the Total Dose level where parametric and functionality failures occur. The lowest Total Dose failure level is dictated by whichever failure occurs first – parametric or functionality. The highest passing level is dictated by no parametric or functional failures.
8. Extended room anneal is performed in accordance with MIL-STD-883E, Method 1019.5, paragraph 3.11.
9. Each completed wafer that is accepted for radiation-qualified products is die-banked for future use.
10. A customer may purchase a whole or partial wafer lot. If the entire lot is purchased, the radiation-qualified wafer is die banked pending the customer's release of the remaining die or until all usable die from that lot are delivered. If only a small quantity of die is purchased from a radiation-qualified wafer lot, the die balance remains available to other customers.
11. Various types of data are provided to the customer, i.e., raw data, statistical data, delta data, or box plots (distribution) of the radiation data, as requested on the customer purchase order.
12. There are several approaches to purchasing radiation-guaranteed product. Radiation-hardened space product generally incur the highest cost due to the extra non-radiation test issues and requirements of V-Level processing.
13. Wafer and lot traceability are automatic on all RHA products.
14. Radiation data on National's Logic products is guaranteed if National in South Portland, Maine, performs the radiation tests.

**Complete Testing and Characterization**

Total dose testing is performed by National Semiconductor in its South Portland, Maine, facility using an NRC-licensed and NIST-certified Gammacell 220. Both in-flux and remote radiation testing can be performed on each device type. After each total dose radiation level, MCT or LTX automatic testers are used to perform complete parametric and functional testing. All irradiation testing is performed in accordance with MIL-STD-883E, Method 1019.5. As requested by our customers, other testing can also be completed. FACT wafer fabrication is DSCC-certified to QML-V.

National's Mil/Aero Logic testing goes beyond radiation qualification. Research and development radiation testing is regularly performed, providing insight to threshold voltage shifts, field oxide hardness, time dependent effects, and more. Radiation testing is performed on transistors, diodes, and capacitors of wafer fab process monitors. As progress is made toward more in-depth understanding of various radiation effects, changes in pro-

cessing, layout, and circuit design will occur to increase the particular technology's radiation resistance.

Transient radiation testing has been performed on FACT product by Boeing Radiation Effects Lab (BREL) in Seattle, Washington. These tests verify the inherent latchup-free capability of FACT-Epi product. FACT products have been manufactured on a thin Epi-CMOS process with low-resistivity material since December, 1987.

Upset data is also available. While sequential circuits and memories (SRAM) will suffer from a soft error (upset), a system's design approach can correct this problem. However, combinatorial circuits experience temporary upset before recovering to their original state.

### All About National's Santa Clara, California, REL

#### Santa Clara, California

- National's Santa Clara Gammacell 220 is used for research and characterization of total dose effects using the current revision of MIL-STD-883, Method 1019. The Gammacell 220 produces gamma radiation photons of approximately 1.25MeV in energy. The dose rate in the gammacell is maintained between 50 and 300 rads(Si)/sec with an accuracy of ± 10%.
- Certification and calibration of this Atomic Energy of Canada Limited Cobalt 60 irradiation unit model Gammacell 220 is performed by using the NIST calibration package.
- Dose rate may be adjusted between 10 rads(Si)/s and 110 rads(Si)/s.
- Thermoluminescence dosimetery (TLD) is performed according to MIL-STD-883, Method 1019. Actual dose rate for individual test is calculated from the exponential decay approximation of the dosimetry data. TLD usage is described in ASTM-E668 *(see list on page 119)*.

#### Test Methodology – California

Total dose radiation tests are designed to characterize changes in device performance due to total dose radiation. These tests are not intended to classify maximum radiation tolerance of any particular device. Rather, they show trends in the critical parameters as a function of total dose. Whether a device meets tolerance requirements is determined by the designer. In many occasions, designers have the ability to circumvent radiation effects by adding appropriate shielding or compensating for performance variations.

MIL-STD-883, Method 1019, is used as a guideline for these tests. Radiation test samples are irradiated under dose rate condition A which tests for total dose effects. Samples are kept biased while irradiating. Dose rate is between 50 - 300 rads(Si)/s.

#### The Step-by-Step Process – California

1. *Pre-irradiation electrical test* – All test samples are verified to be functionally and parametrically working prior to irradiation. They are subject to group A qualification test, including burn-in. Samples are verified to be within room temperature acceptance limits.
2. *Test Environment* – Samples are enclosed in a lead/aluminum container. During irradiation, this container is vertically aligned with the source of radiation. Ambient temperature throughout the test is approximately +25˚C.
3. *Biasing* – All devices under test are kept biased during irradiation. The bias circuit that is used for burn-in also is used for irradiation.
4. *Electrical test* – Remote electrical tests are performed on the irradiated devices at several total dose levels. All samples are short circuited while transporting to the automatic electrical tester. Electrical tests are completed within two hours of each irradiation step.

# Notes