NESC-PL-23-01945 Single-Event Latch-up in Commercial Electronics: Risk Assessment and Mitigation

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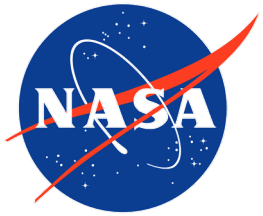
Presentation Overview



- **Introduction and Motivation**
- **Task Technical Details**
- **Pathfinder Effort**
- **Closing Remarks**

Introduction and Motivation

- There is an increasing drive for NASA program and projects to use commercial-off-the-shelf (COTS) electronic parts and components including in critical systems.
  - COTS parts can provide superior performance and availability over their RHA counterparts.
  - Conversely, COTS parts are not intended for space applications and require qualification for the space environments such as Radiation
- A previous investigation found that that 50% of commercial CMOS devices were susceptible to radiation-induced single-event latch-up (SEL), and the SEL was destructive in 50% of those cases
- Utilization of devices susceptible to “recoverable” SEL is sometimes accepted with mitigation techniques such as including power cycling with external latch-up detection circuitry.

What is SEL and why does it matter?

- Parasitic thyristor (silicon-controlled rectifier SCR) structure in CMOS parts can be activated by an ion strike
- The part is subject to sustained high current
- The effects can be up to catastrophic failure due to burnout (destructive SEL)
- But in some cases the part is still functional after power cycling (“recoverable” or non-destructive SEL)

Question: Is the device still reliable after experiencing recoverable SEL?

Introduction and Motivation (continued)

- It has been reported some “recoverable” or “non-destructive” SEL compromise part reliability due to latent damage
  - Latent damage: high-current-density overstress of the metallization layers that is not immediately noticeable as performance degradation.
  - Reference GSFC NASA Advisory NA-GSFC-2005-05.
- The reliability implications of SEL in such devices are not well-understood, increasing Program risk.
  - Nor is the efficiency of typical mitigation techniques to prevent the reliability implications

No formal NASA guidance exists for reliability evaluation of COTS exposed to radiation, or regarding validated mitigation approaches.

Introduction and Motivation

- NASA Engineering Safety Center's (NESC) is an agency-wide collaboration with the mission to perform value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success (https://www.nasa.gov/nesc/)
- In December 2024, NESC authorized task NESC-PL-23-01945 "Single-Event Latch-up in Commercial Electronics: Risk Assessment and Mitigation"
- The scope of the task is to "provide engineering guidance to SEL risk characterization and risk management"

Development of practical engineering guidelines for qualification and use of COTS parts susceptible to recoverable SEL

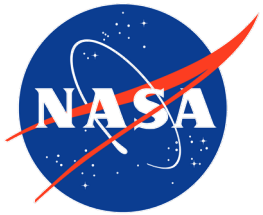
Example Knowledge Gaps for Investigation

- Consequence –the ability to bound SEL manifestation as truly non-destructive vs. damage-inducing.
  - If damage-inducing, what is the consequence in terms of lifetime/reliability reduction, especially during critical mission phases?
  - What is the confidence that the application-specific worst-case effect are manifested during radiation testing?
  - What are recommended failure analysis procedures and potential markers of reliability reduction?
- Likelihood –the current state-of-the-practice accurate rate prediction requires extensive heavy ion characterization
  - What is our ability to bound SEL rates based on constrained test data (vis-a-vis radiation facility availability)?
- Mitigation strategies
  - How do we validate circuit and system-level mitigation?

Assessment Technical Activities

- Initial assessment of current knowledge
  - Survey databases of available radiation data
  - Survey of available mitigation approaches
  - Develop test criteria: e.g., circuit mitigation, number of SELs, time required in SEL mode
- Selective testing (radiation, laser, failure analysis, and reliability testing) will be carried out to fill in knowledge gaps identified above.
  - Targeted part types: A/D (2-3), Power (1-2), SRAM (1)
    - Need statistically significant number of samples (30-50)
  - Construction analysis for identification of SEL-susceptible features (bond wires, metallization)
  - Heavy ion and laser SEE testing to manifest and characterize SEL
    - IR inspection possible during laser testing to identify affected features
  - Non-destructive failure analysis (thermal analysis, optical imaging) to identify damage markers
  - Reliability testing to assess reduction of lifetime due to SEL
  - Implement and assess mitigation efficiency in heavy ion or pulsed laser SEE testing
- Development of practical engineering guidelines for qualification and use of COTS parts susceptible to recoverable SEL and final NESC Report

Life Testing and Destructive Analysis Plans



Virgin control samples
Condition: intact package

Heavy Ion samples
Condition: intact package

Laser SEE samples
Condition: previously decapsulated package

Infrared microscopy of powered samples to look for hot spots suggesting presence of damage

Static Burn In for *2000 hrs at Max Operating Temperature*, with **intermittent functional** checks at 100hrs, 250hrs, 500hrs, 1000hrs, 1500hrs, 2000hrs.
If **intermittent functional** fails: remove device from test

Fault isolation and Failure Analysis of failed devices to demonstrate location of failure

Closing Remarks

- Under NESC, NASA is currently pursuing a directed effort to develop engineering guidance to SEL risk characterization and risk management
- The original proposed period of performance was one year but it may change due to programmatic constraints
  - Interim outbriefs are planned for NASA Program stakeholder

Thank you for your attention!