Memories and NASA Spacecraft: Part 2 – Future Developments

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Abstract

• In this presentation, we delineate the NASA Electronic Parts and Packaging (NEPP) approach to future NVM evaluation and qualification efforts
Outline of Presentation

• NEPP Overview
• NEPP General FY11 Plans
• NEPP and NVMs
NEPP Overview

- NEPP supports all of NASA for >20 years
  - 7 NASA Centers and JPL actively participate
- The NEPP Program focuses on the reliability aspects of electronic devices
  - Three prime technical areas: Parts (die), Packaging, and Radiation
- Alternately, reliability may be viewed as:
  - Lifetime, inherent failure and design issues related to the electronic parts technology and packaging,
  - Effects of space radiation and the space environment on these technologies, and
  - Creation and maintenance of the assurance support infrastructure required for mission success.
- NEPP does not qualify specific devices, but determines HOW to qualify as well as investigating new radiation/reliability concerns

Electrical overstress failure in a commercial electronic device
NEPP Works Two Sides of the Equation

• Assurance
  – Issues that are applicable to space systems being designed and built (i.e., currently available technologies)
  – Examples
    • Cracked capacitors
    • DC-DC converter reliability
    • Enhanced Low Dose Rate Sensitivity (ELDRS)
  – Communication infrastructure via website and working groups
    • NASA Electronic Parts Assurance Group (NEPAG)
  – Audit and review support

• New electronics technology
  – Issues that are applicable to the next generation of space systems in conceptualization or preliminary design
  – Examples
    • 45-90 nm CMOS
    • SiGe
    • State-of-the-art FPGAs
  – Collaboration with manufacturers and government programs for test, evaluation, and modeling
  – Development of new predictive performance tools
The NEPP Program

Management

Ken LaBel
Radiation Effects
Advanced Actives
NEPP Events

Mike Sampson
NEPAG
Passives
Packaging

Core Elements

Electronic Parts Reliability
Radiation Effects
Parts Assurance (NEPAG)
Advanced Packaging
Information Dissemination

Focus Technologies

Extreme Environments
Sensor Technology
Fiber Optics
Power Devices
Radio Frequency
Lead-free
Memories
Discretes
Embedded Technologies
Systems on a Chip (SOC)

SiGe Mixed Signal
Area Arrays
Programmable Logic
Interconnects

Products/Deliverables

Guidelines
Specifications and Standards
NASA Parts Selection List
Website Content
Technical Reports

Specifications
Tools
Data
Bodies of Knowledge

Test Methods
Papers

Typical Spacecraft Electrical Architecture

The 90/90 Goal

Sample NEPP Technology Areas
Memories
FPGAs
Capacitors
SiGe
Power devices

90% of NEPP efforts should support
90% of NASA flight missions

**Typical Spacecraft Electrical Architecture**

**The 90/90 Goal - Example**

![Diagram of spacecraft electrical architecture]

**Sample NEPP Technology Area**

**Memories**

Used in any processing application and for data storage on a spacecraft.

Generic issue!

NEPP Has a Wide Range of Efforts

• Tasks vary extensively in the technologies of interest
  – Building blocks like capacitors
  – Standard products like DC-DC Converters, linear bipolar devices, and A-to-D Converters
  – New commercial devices such as FPGAs and memories
  – Test structures on emerging commercial or radiation hardened technologies
  – Specialized electronics such as IR arrays and fiber optics
  – New assurance methods and investigations

• Currently in FY11 planning cycle
  – PRELIMINARY PLANS FOLLOW
    • Active devices only shown (packaging, NEPAG – not shown)
FY11 Radiation Plans for NEPP Core (1)

Core Areas are **Bubbles**; Boxes underneath are variable tasks in each core.

**NEPP Research Categories – Active Electronics**

- **SiGe. Mixed Signal**
  - SiGe on SOI
  - Scaled SiGe
  - Advanced Data Conversion, Amplifiers, Drivers
  - Architectural comparison
  - Develops students at Georgia Tech, Vanderbilt, Auburn

- **Scaled CMOS**
  - Commercial Devices
    - Memories – Non-volatile, volatile
    - FPGAs
    - Processors, SOCs
    - Structured ASICS
  - Test Structures
    - Silicon on Insulator (SOI)
    - Ultra-low power
    - 32 and 45 nm
    - CNTs
    - RHBD Support
  - Partners include: AFRL, Cypress, Ball, DoD, IBM, TI, Intel, Boeing, Actel, Atmel, Xilinx, Altera, Cypress

- **Sensor Technologies**
  - IR
  - Visible
  - Cryo SEL
  - Others

- **Photonics**
  - Fiber Amplifiers
  - Exotic-doped Fiber components
  - Wavelength Division Multiplexing
  - Free space Optical interconnects
  - Fiber Data Links
  - Optocouplers and PM Optocouplers

- **Performance Tools**
  - 32 and 45 nm CMOS
  - SiGe
  - Low proton energy
  - Compact model based rate prediction

Develops students at Vanderbilt

Legend

- DoD and NASA funded
- NASA-only funded
- Overguide

FY11 Radiation Plans for NEPP Core (2)

Core Areas are Bubbles; Boxes underneath are variable tasks in each core

NEPP Research Categories – Hardness Assurance

ELDRS Test
- NSC, LT, TI, Intersil, STM Support
- Hydrogen Effects
- High dose

Temperature Effects
- SEE - Elevated
- SEE - Cryo
- TID – Elevated post
- TID – Elevated during
- Cryo BOK

Power Devices
- SEGR Model/Tool
- Vendor Eval
- POLs
- GaN, SiC
- High V DC-DC

Combined Effects
- NVMs – Radiation and Reliability
- TID on SEE
- DDD on SEE
- SETs on Reliability
- <90nm Reliability of Irradiated Devices
- Heavy Ion DD of<65nm

Guidelines
- ADC Test
- Low Proton Energy
- SOC Test Guideline
- NVM Test Guideline
- Standard FPGA Test Method
- SDRAM Test Guideline

Other Overguide Tasks
- Education/training modules
- Microwave Technologies
- Additional SOC Testing

Legend
- DoD and NASA funded
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Partners at vendors listed, RLP Research, ASU

FY11 Parts Plans for NEPP Core (1)

Core Areas are **Bubbles**; Boxes underneath are variable tasks in each core

**NEPP Research Categories – Parts Assurance**

- **SiGe. Mixed Signal**
  - Cold temperature effects
  - Scaled SiGe
  - Advanced Data Conversion, Amplifiers, Drivers
  - GaAs, InP, Antemonides

- **Scaled CMOS**
  - Commercial Devices
    - Memories – Non-volatile
    - FPGAs
    - Processors, SOCs
    - Memories - SDRAM
  - Test Structures
    - Silicon on Insulator (SOI)
    - Ultra-low power
    - 32 and 45 nm
    - CNTs
    - Sub 90nm

- **Sensor Technologies**
  - IR
  - Visible
  - ROICs - Cryo
  - Others

- **Photonics**
  - Fiber Amplifiers
  - Exotic-doped Fiber components
  - Wavelength Division Multiplexing
  - Free space Optical interconnects
  - Fiber Data Links
  - Optocouplers and PM Optocouplers

- **Rf Electronics**
  - RF Reliability Guide
  - Advanced RF

Legend

| NASA-only funded | Overguide |

FY11 Parts Plans for NEPP Core (2)

Core Areas are Bubbles; Boxes underneath are variable tasks in each core

NEPP Research Categories – Parts Assurance

Passives
- Polymer Caps
- BME Caps
- Embedded Passives
- Advanced devices

Temperature Effects
- Cryo CMOS
- Mixed Signal - Cryo
- Extended COTS
- Hot spot test method
- Cryo BOK

Power Devices
- Power Mosfets
- DC-DC Eval
- POLs
- GaN, SiC
- High V DC-DC

Combined Effects
- NVMs – Radiation and Reliability
  - TID on SEE
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  - SETs on Reliability
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Guidelines
- ADC Test
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Other Overguide Tasks
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- Additional SOC Testing
NEPP and Memories

• Top level agenda
  – Evaluate scaled commercial SDRAMs and NVMs
    • Radiation tests first
      – If reasonable, reliability and combined radiation/reliability
  – Work with new memory technologies and manufacturers considering entry into Mil/Aero market
    • PCM
    • MRAM
    • RRAM
    • DDR3, and so on
  – We do not QUALIFY devices, but evaluate suitability of devices and determine appropriate qualification methods and physics of failure
NEPP Radiation Evaluations - NVM

- Commercial Flash Memories
  - Manufacturers evaluated (1-32 Gb per device)
    - Micron, Samsung, Hynix, ...
    - TID is mostly > 50 krads-Si
      - Biased/unbiased tests
      - Low and high dose rate tests (only Samsung showed significant improvement at low dose rates)
  - Most NVM cells have fairly good SEU tolerance and it’s the surrounding circuits that have SEU sensitivity
    - SEL varies by manufacturer
      » Current spikes noted during some heavy ion tests are being evaluated
    - SEFIs are a prime issue
  - Focus has been on Single Level Cell - SLC
    - Multi Level Cell - MLC has lower cell margins and data shows typically less radiation tolerance
    - Further scaled, MLC, and higher density to be evaluated in FY11
Alternate Material NVMs – Repeat from This Morning

• Alternate material NVMs – evaluated as devices become available
  – Expect cell integrity to perform fairly well under irradiation on most NVMs
  – LaBel’s Truism:
    • There are ALWAYS more challenges in “qualifying” a new technology device than expected

• Phase change memories (PCM)
  – Density, speed, and power look promising
    • Temperature is the challenge
  – Ex., Samsung, Numonyx – initial data taken

• MRAM
  – Spin Torque appears to improve SWaP metrics
  – Ex., Avalanche Technologies

• Resistive Memories
  – Ex., Unity Semiconductor, HP Labs
    • Unity’s talking about a 64Gb device by next summer!

• NVSRAMs
  – Ex. Cypress

• CNT

Combining Radiation and Reliability - NVMs

- FY09 began new studies on Flash memories combining TID with endurance
  - **Result:** TID did NOT degrade endurance properties at room temperature
- Considerations for FY11
  - Perform TID and lifetime/data retention tests
    - Must be carefully planned since high temperature typically used for accelerated life/retention tests has two inherent issues with Flash/NVM
    - Anneals radiation damage
    - May cause bit flips above commercial operating temperatures
  - Develop radiation qualification guideline document
  - Continue efforts on reliability – latency, bit disturb, et al

![Graph showing Average Error Count per thousand cycles vs. Dose (krads (SiO2))]