Short Course

COURSE DESCRIPTION

A one-day Short Course "Selection of Integrated Circuits for Space Systems" will be presented at the 2009 Nuclear and Space Radiation Effects Conference (NSREC). With the advent of commercial devices dominating the semiconductor market, the decision process for selecting ICs for space systems has become more complex. In this short course, we provide a discussion of these processes and the risk trades involved. The main concepts revolve around the selection of device types (i.e., what circuits are appropriate to provide a function), as well as the question of commercial-off-the-shelf (COTS) versus radiation hardened (RH) components.

The Short Course is organized into six sessions starting with a systems engineering and management perspective for selection. The second through fourth sessions delve into the technical considerations: radiation, reliability, and design performance. Finally, two examples will be provided focusing on advanced digital and mixed signal applications, respectively.

The speakers for the 2009 Short Course are all experts in their respective areas. They will present the knowledge base in their topical areas extending the information beyond the traditional radiation effects short course and providing a larger perspective on the issues including COTS versus RH trades. The speakers will focus on determining the relevant characteristics that should be weighed for selection.

The course is applicable to designers, radiation effects engineers, component specialists, and other technical and management personnel who are involved in developing reliable systems not only for the space environments, but for other radiation environments as well. This course provides a unique opportunity for NSREC attendees to benefit from the expertise of the instructors, as well as the in-depth coverage and application-oriented perspective provided by the short course format. Each instructor will develop the core content of their respective topics from background material largely found in the literature and from their unique interactions with actual space systems. As such, the course will benefit both new and experienced engineers, scientists, and managers. In-depth notes will be provided at registration.

CONTINUING EDUCATION UNITS (CEUS)

For those interested in Continuing Education Units (CEUs), there will be an open-book test at the end of the course. The course is valued at 0.6 CEUs and is endorsed by the IEEE and the International Association for Continuing Education and Training (IACET).

SHORT COURSE CHAIRMAN

Ken LaBel
Short Course Chairman

Ken LaBel has worked at NASA since 1983 after graduating from The Johns Hopkins University with a BES in EECS. His career at NASA has included:

- Hardware/software for ground systems,
- Advanced technology,
- Flight hardware,
- Systems engineering, and,
- Radiation hardness assurance/research for >50 NASA projects.

Mr. LaBel has published over 100 papers as author/co-author and is a recognized expert in radiation effects systems engineering. He has won best presentation awards at the Government Microcircuits and Applications Conference (GOMAC) and at IEEE Radiation Effects Data Workshop (REDW), and nominated at Radiation Effects on Components and Systems (RADECS) conference, NSREC, and Hardened Electronics and Radiation Technology (HEART) Conference. Mr. LaBel has taught three short courses at the RADECS, and one each at NSREC and HEART. He is an IEEE member.

PROGRAMMATIC ASPECTS OVERVIEW

John M. Stone
Southwest Research Institute

John Stone has 22 years experience in space-flight electronics development. He graduated from Trinity University in 1984 (BS Engineering Science) and from the University of Texas-Austin in 1986 (MSE Electrical Engineering.) At SwRI since 1987, he has worked as a designer, systems engineer, and project manager on C&DH and science electronics development programs and has served as an external reviewer and analyst for the GSFC Explorer's program. He is currently a payload systems engineer with responsibility for reliability and radiation effects activities for the MMS mission instrument suite. First introduced to radiation effects issues in 1992, he has become increasingly interested in the field, attending every NSREC since Atlanta in 2004. He is a member of IEEE and NPSS and is currently chief engineer in Southwest Research Institute's Department of Space Systems.

John Stone will discuss the programmatic (cost and schedule) aspects of hardware development for the radiation environment. Too often, systems, hardware development, and radiation engineers don't understand the impact that their work has on the programmatic success of a given project. This section of the short course will emphasize the close link between everyday engineering and programmatic success. After an overview of the scope and importance of programmatic issues, Mr. Stone will discuss the connection between those issues and the requirements definition process. This will be followed by a discussion of the programmatic impact created by product implementation and assurance activities. A variety of practical examples drawn from various projects will be used to illustrate the points made.

Introduction

- Short course goals
- The "ideal" program
- Programmatic introduction
- Programmatic success drivers
- Importance

Programmatic Impacts from Requirements Definition Activities

- "The prime requirement"
- Types and characteristics of requirements
- Competing desires drive programmatics
- The importance of balance
- Application

Programmatic Impacts from Product Implementation Activities

- An important distinction
- Implementation trade Studies
- Sample implementation choices and programmatic implications
- Application

Programmatic Impacts from Radiation Assurance Activities

- Sample issues and programmatic implications
- Application

Conclusion

Keith Avery is the Program Lead for the Integrated Microsystems program at the Air Force Research Laboratory focusing on advanced packaging and optoelectronics for space. He received his BS degree from DeVry Institute of Technology in 1983. For the first 12 years of his career he worked in the commercial sector designing digital and analog circuits for commercial, industrial, and telephony applications. Prior to joining AFRL he worked as a government contractor performing design activities for space experiments, advanced packaging techniques, and radiation effects on micro-electronics. During his career he has increased his level of responsibility for design activities and program management. He has authored or co-authored numerous papers on designs for space and radiation effects. Mr. Avery is a member of IEEE and NPSS.

RADIATION EFFECTS POINT OF VIEW

Keith Avery
Air Force Research Laboratory

Keith Avery will discuss what is meant by the term “radiation hardened” (RH) as it applies to modern micro-circuits. This includes total ionizing dose (TID) and single event effects (SEE) along with mitigation techniques that are available. The designer is left performing a tradespace between using commercial-off-the-shelf (COTS) devices vs. radiation hardened devices as it applies to a board level design and an example will be shown. This tradespace will include items such as cost of upscreening a COTS part, cost of an ASIC development, and the impacts on size, weight, and power (SWAP) when making those choices. Woven into these trades is the overriding factors of mission risk and mission cost which will impact each decision.

Introduction

The Environment
- Solar Cycles
- Solar Flares
- Coronal Mass Ejections
- Orbit Dependency

Radiation Effects
- Ionizing
- Non-Ionizing
- Single Event Effects

Mitigation Techniques
- Shielding
- Design Techniques

Mission Example
- Mission Parameters
- Design Choices
- Rad-Hard vs. COTS

Summary

Dr. Sheldon is currently the Group Supervisor for Electronic Parts Engineering at the Jet Propulsion Laboratory. He is also a principal investigator in areas of non-volatile memory and FPGA research and has been at JPL since 2003. Dr. Sheldon has over 25 years experience in the development, manufacture and application of semiconductors. He has held various engineering and management positions at companies that include Agilent Technologies, Lattice Semiconductor, Racom Systems, Ramtron and Inmos. Dr. Sheldon has a BA in Physics from the University of Colorado, an MS in Physics from the University of Oregon and a Doctorate in Management from Colorado Technical University.

RELIABILITY CONSIDERATIONS

Doug Sheldon
Jet Propulsion Laboratories

Doug Sheldon will focus on the understanding of reliability as it pertains to individual devices, as well as to systems. The continued evolution in parts technology requires a similar evolution of reliability considerations for successful risk management of mission requirements. This talk will provide a framework of modern reliability tools and concepts as they relate to risk management. A mathematical framework will be established based on process technology and physics of failure models. These concepts are then integrated with quality metrics. This fundamental inter-relationship between quality and reliability is then used to define appropriate risk management tools that can be used by engineers and managers to correctly evaluate parts. With these interrelationships appropriately defined, such concepts as lifetimes, screening levels, etc. can now be accurately implemented.

IC Technology Trends

Generalized Reliability Overview

Thermodynamics Fundamentals

Acceleration Models and Statistics

Yield and Screening

Burn In and Scaling

Examples

Modern Techniques and Future Trends

Dr. Kirk Kohnen is a Senior Scientist with Boeing's Space and Intelligence Systems (S&IS) division. He holds a BS degree in Information and Computer Science (1982) and BS (1982), MS (1984), and Ph. D. (1988) Degrees in Electrical Engineering from the University of California, Irvine. He joined Hughes Aircraft in 1981 and held Hughes Master's and Doctoral fellowships. Currently, Dr. Kohnen is a Boeing Associate Technical Fellow and an adjunct professor at Loyola Marymount University, Los Angeles, teaching graduate classes in microprocessor system architecture. Dr. Kohnen has been developing system architecture techniques for single event mitigation since joining Hughes Space and Communications in 1998. He holds 14 US patents, including two in the field of single event effects mitigation.

Kay Chesnut Jobe is a Chief Scientist with Boeing's Space and Intelligence Systems (S&IS) division. She received a BS in EE from University of Colorado in 1980. She joined Hughes Space and Communications in 1980 where she designed and implemented timing systems for space applications. She has developed seminal principles for determining the impacts of single event effects on multi-GHz RF circuitry used for the clocking of digital logic. Currently, Kay is a Boeing Technical Fellow where she isolates, understands and fixes anomalies both for systems in test and satellites on orbit. Kay also works extensively in the radiation community; she has served as NSREC's 2003 Finance Chair, 2005's Local Arrangements Chair, as Secretary for the Radiation Effects Steering Group in 2006, and is the Conference Chair for the upcoming 2011 NSREC (See you all in two years!)

ELECTRONIC DESIGNER'S PERSPECTIVE

Dr. Kirk Kohnen and Kay Jobe

Boeing Space and Intelligence Systems (S&IS)

Dr. Kirk Kohnen and Kay Jobe will discuss the challenges faced by electronic systems designers in the selection of ICs for space missions. Commercial electronic devices provide substantial improvements in SWAP when compared with their RH counterparts. System requirements often will drive these non-RH ICs to be inserted into systems. However, since these parts are not designed to tolerate the space environment, tradespaces exist for design and system complexity as it relates to the successful device insertion. Dr. Kohnen and Ms. Jobe will focus on the electrical performance requirements that drive the selection of state-of-the art technologies and the enabling features that systems desire. A discussion comparing modern commercial device performance versus the RH options will be presented. This will be followed by an overview of applying the general challenges described in Parts 1-3 for state-of-the-art device offerings using practical samples for actual missions.

Introductory Comments

Straw-Man Requirements

- Total Dose
- Single Event Effect Rates
- It's a Competition

Electronic Trade-offs

- COTS vs. RH ASICs
- COTS vs. RH SRAM
- COTS vs. RH DRAM
- COTS vs. RH FPGA
- COTS vs. RH A/D

Technical Trade-offs

- Capability vs. Availability
- Hierarchy of Design Trade-offs
- COTS-Driven Packaging Issues
- Wearout Mechanisms
- COTS Wearout Mechanism Mitigation
- Hidden Circuitry

Summary and Concluding Remarks

Melanie Berg received her MS degree in Electrical Engineering from the University of Pittsburgh in 1990. In 1990 Ms. Berg joined IBM's ASIC Advance Logic Design Team in Poughkeepsie NY. She has been part of several development teams responsible for high speed multi-million gate ASIC and complex FPGA implementations. Ms. Berg is currently a member of IEEE and has joined the Radiation Effects and Analysis group at NASA Goddard Space Flight Center. She has published and presented several papers concerning such topics as Reliable Synchronous Design Methodology, Mitigation Strategies for Critical Circuitry, and Hardness Assurance for Space Flight Projects. Ms. Berg is presently investigating radiation effects and applicable mitigation strategies for the potential insertion of Field Programmable Gate Arrays (FPGAs) and ASICS into critical space flight projects.

EXAMPLE 1: TRADING ASIC AND FPGA CONSIDERATIONS FOR SYSTEM INSERTION

Melanie Berg

MEI Technologies Inc.

Melanie Berg will utilize the concepts discussed in Parts 1-4 for the selection of high performing digital devices. The presentation will begin with general definitions and comparisons of the varying device architectures. Within this section, similarities and differences of ASICS and FPGAs will be presented focusing on the radiation, reliability, and design performance aspects. A brief discussion of radiation effects and mitigation strategies specific to ASIC and FPGA design implementation will follow. A sample trade will be performed illustrating how the information provided in previous sections is used for selecting an FPGA or ASIC for space missions.

Motivation and Trends
- **Flexibility vs. Efficiency**
- **In-flight Reconfigurable Computing**

Device Selection Process
- **Flow Diagram**
- **Device Characteristics**
  - **Commonalities**
  - **Differentiation**
  - **Fault Tolerance**

Single Event Upsets (SEUs)
- **Generation**
- **Propagation**
  - **Capacitance Effects**
  - **Frequency Effects**
- **Capture**
  - **Static**
  - **Dynamic**

Preliminary Design Development
- **Custom ASIC**
  - **SEU susceptibility**
  - **Common Mitigation**
  - **Preliminary Architecture**
  - **Potential Risk**
  - **Error Prediction**
- **Anti-fuse FPGA**
  - **SEU susceptibility**
  - **Common Mitigation**
  - **Preliminary Architecture**
  - **Potential Risk**
  - **Error Prediction**
- **SRAM based FPGA**
  - **SEU susceptibility**
  - **Common Mitigation**
  - **Preliminary Architecture**
  - **Potential Risk**
  - **Error Prediction**

Power Trade

Reliability Analysis

Schedule Impact

Summary

Dr. Steven C. Moss is Director of the Microelectronics Technology Department at The Aerospace Corporation. He holds a BS Degree (Arkansas A&M College, 1970, physics and mathematics), a MS Degree (Purdue University, 1972, physics), and a Ph. D. Degree (North Texas State University, 1981, physics). He held a NRC-NRL Post-Doctoral Associateship at NRL (1981-1982) and worked as Visiting Assistant Professor with the Center for Applied Quantum Electronics at North Texas State University (1982-1984). He joined The Aerospace Corporation in 1984, where he has held positions with increasing responsibility since. Dr. Moss is a member of APS, OSA, MRS, SPIE, AAPT, and is a senior member of the IEEE. He has served for 13 years as Treasurer of the SEE Symposium and on its organizing committee.

EXAMPLE 2: TRADING MIXED SIGNAL DEVICES FOR INSTRUMENT OR HIGH-PRECISION APPLICATIONS

Dr. Steven C. Moss
The Aerospace Corporation

Dr. Steven C. Moss will discuss trades associated with using analog-to-digital converters for sensor applications for space systems. Types of ADCs and metrics commonly used to evaluate ADCs will be presented, followed by a discussion of how ADCs are used in conjunction with sensors such as focal plane arrays. The sensitivity of ADCs of various types to space radiation effects including total integrated dose, displacement damage, and single event effects will be discussed. Generic reliability issues, as well as those specific to ADCs will be discussed. Tradeoffs between performance, resource requirements, reliability, and radiation sensitivity will be discussed. Finally, advanced ADCs and the direction of research into ADCs will be discussed.

Introduction

Sensor Example: Analog Signal Chain for Imaging Focal Plane Array

Analog Signal Chain Trade Space
- **Discrete Component Options vs Integrated Solutions**
- **Imaging Focal Plane Array Options**
- **Control Electronics**
- **Post-FPA Sampling Options**
- **Gain Stage Options**
- **Voltage Reference Options**
- **Analog-to-Digital Converter (ADC) Options**

Analog-to-Digital Converters
- **How are ADCs used in conjunction with sensors?**
- **Types of ADCs**
- **Metrics for ADCs**
- **ADC Test Standards**

Specific Issues for use of ADCs in Space
- **Radiation sensitivity of ADCs**
- **ADC reliability issues**

Trade Spaces
- **Performance**
- **Resource requirements**
- **Radiation sensitivity**
- **Reliability**

Future ADCs
- **Advanced microelectronic ADCs**
- **Photonic/optoelectronic ADCs**

Summary