Short Course Program

SOFT ERRORS: FROM THE GROUND UP

ARIZONA BALLROOMS 6 AND 7 – MONDAY, JULY 14

7:30 AM	**REGISTRATION/CONTINENTAL BREAKFAST**
8:00 AM	**SHORT COURSE INTRODUCTION** Jeffrey Black *Vanderbilt University*
8:10 AM	**PART 1 – FUNDAMENTAL MECHANISMS FOR SINGLE PARTICLE-INDUCED SOFT ERRORS** Robert Reed *Vanderbilt University*
9:45 AM	**BREAK (ARIZONA FOYER)**
10:10 AM	**PART 2 – GROUND-BASED TESTING AND EVALUATION OF SOFT ERRORS** Craig Hafer *Aeroflex Colorado Springs*
11:45 PM	**SHORT COURSE LUNCHEON (TUCSON BALLROOM)**
1:00 PM	**PART 3 – SOFT ERROR RESULTS ANALYSIS AND ERROR RATE PREDICTION** Edward Petersen *Consultant*
2:35 PM	**BREAK (ARIZONA FOYER)**
3:00 PM	**PART 4 – SOFT ERROR CASE STUDIES** Joseph Benedetto *Radiation Assured Devices* Jeff Wilkinson *Medtronic, Inc.*
4:40 PM	**WRAP-UP**
4:50 PM	**EXAM (only for students requesting CEU credit)**
5:20 PM	**END OF SHORT COURSE**

Short Course

COURSE DESCRIPTION

A one-day Short Course "Soft Errors: From the Ground Up" will be presented at the 2008 Nuclear and Space Radiation Effects Conference (NSREC). This Short Course will provide a review of soft errors, also known as single event upsets, applying the "From the Ground Up" theme in many ways. The Short Course is organized into four sessions starting from a foundation of the mechanisms for the generation of soft errors. The second session will build on that foundation and cover the ground-based testing and evaluation of soft errors. How the results of soft error testing and evaluation are analyzed and applied to predict soft error rates follows in the third session of the Short Course. Finally, the last session will provide two different case studies of soft errors in microelectronic systems, one looking at a complex device in a space-based application and one looking at a simple device in a ground-based medical application.

The speakers for the 2008 Short Course are all experts in their respective area of soft errors. They will present the traditional knowledge base in their topical area and build upon that knowledge with current results that demonstrate where the knowledge base is being stretched. Examples of this include the decrease of the separation of charge collection volumes, the increase in the speed of microelectronic devices, and the application of novel circuit design techniques. The speakers will also discuss the challenges of applying ground-based testing and evaluation results to the prediction of space-based soft error rates.

The course is applicable to designers, radiation effects engineers, component specialists, and other technical and management personnel who are involved in developing reliable systems designed to operate in terrestrial and space environments. 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. 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

Jeffrey Black
Short Course Chairman

Jeffrey Black is a Senior Research Engineer in the Institute for Space and Defense Electronics (ISDE) at Vanderbilt University. He received his BSEE at the United States Air Force Academy in 1988 and MSEE at the University of New Mexico. He expects to complete his Ph.D. degree at Vanderbilt University in 2008. Jeff's research interests run the gamut of radiation effects as they relate to circuit design and hardness assurance. Prior to joining ISDE in 2004, Jeff worked for Mission Research Corporation in Albuquerque, NM. He has served NSREC as Secretary of the Radiation Effects Steering Group from 2003-2006, Short Course Speaker in 2006, Radiation Effects Data Workshop Chair in 2004, and Local Arrangements Chair in 2002.

After completion of his Ph.D. (Clemson 1994), **Robert Reed** worked as a post-doctoral fellow at the Naval Research Laboratory and later worked for Hughes Space and Communication. From 1997 to 2004, Robert was a research physicist at NASA's Goddard Space Flight Center where he supported NASA space flight and research programs. He is currently an Associate Professor at Vanderbilt University. His radiation effects research activities include topics such as single event effect basic mechanisms and on-orbit performance prediction techniques. He has authored over 80 papers on various topics in the radiation effects area. He was awarded the 2004 Early Achievement Award from IEEE/NPSS and the 2000 Outstanding Young Alumni Award from Clemson University. Robert has been active in the NSREC community since 1992, serving as 2006 Short Course Chairman, 2004 Finance Chairman, 2002 Poster Session Chairman, and 2000 Short Course Instructor.

FUNDAMENTAL MECHANISMS FOR SINGLE PARTICLE-INDUCED SOFT ERRORS

Robert Reed
Vanderbilt University

Prof. Robert Reed will present a discussion on the basic energy deposition, charge generation and collection mechanisms for single event soft errors. The course will begin with a discussion of the physical interactions of radiation with matter that are important to understand single event soft errors. This will be followed by a brief discussion of radiation environments (space and terrestrial). Then he will discuss basic charge generation, transport, and collection mechanisms during a single particle event. Throughout the talk, Prof. Reed will relate the basic mechanism issues to soft error effects in advanced technologies.

Introduction

Interaction of Radiation with Matter
- "Ion Stopping" (Stopping Force)
- Nuclear Reaction (Nuclear Forces)
- Ion Tracks

Radiation Sources
- Space Environment
- Terrestrial Environment

Simple Device Physics
- Holes and Electrons
- The P-N Junction

Charge Generation
- Energy Loss to Ionization
- Direct Ionization
- Indirect Ionization

Charge Collection Mechanisms
- Drift
- Diffusion
- Carrier Density Modulation of Electrostatic Potentials

Summary

Craig Hafer received his B.S. degree from Montana State University and his M.S. Physics degree from Idaho State University in 1989. He started in the industry at AMIS working as a fabrication process engineer for over two years. He began his work at Aeroflex Colorado Springs in 1984 (then Mostek) as a wafer fab process integration engineer. Then at Aeroflex (UTMC) he worked on developing a RadHard wafer fab process, device physics, wafer foundry engineering, and product engineering. Since 2003 he has been responsible for single event effects, total ionizing dose, proton, and prompt dose radiation effects testing of Aeroflex's RadHard standard products (memory, interconnect, logic) and RadHard digital and mixed-signal ASICs. He has authored over 25 papers and presentations at NSREC, GOMAC, HEART, SEE Symposium, RADECs, and has presented radiation effects training at NASA Johnson along with customer training worldwide. He is an IEEE Member and has qualified for and run the Boston Marathon three times since 2006.

GROUND-BASED TESTING AND EVALUATION OF SOFT ERRORS

Craig Hafer
Aeroflex Colorado Springs

Craig Hafer will discuss soft error (SE) testing of modern digital integrated circuits (ICs). SEs due to single ion events can be problematic for proper IC and system level operation. This section of the short course will introduce the purpose of terrestrial SE testing as a method to determine the effects and frequency of single event SEs on IC operation in a space environment. A comparison of galactic cosmic ray (GCR) flux and linear energy transfer (LET) to terrestrial testing flux and LET will be reviewed. Terrestrial ion accelerator SE test facilities will be listed along with a general discussion of test facility considerations. SE test planning, sample preparation, and test hardware and software preparation will be examined. An overview will be made of recent challenges due to complex, dense, high speed, small geometry technology IC devices. By the end of this portion of the short course, attendees will be acquainted with single event upsets (SEUs), single event transients (SETs), and single event functional interrupts (SEFIs).

Introduction

Galactic Cosmic Rays versus Terrestrial Testing
- Galactic Cosmic Ray Flux versus Test Facility Flux
- Galactic Cosmic Ray Ion Energies versus Terrestrial Test Facility Ion Energies
- Linear Energy Transfer versus Depth

Test Facilities
- Soft Error Test Techniques
- Test Facilities
- Test Facilities Considerations

Terrestrial Soft Error Testing
- Test Planning Considerations
- Test Sample Preparation
- Test Hardware Considerations
- Test Software Considerations
- Recent Technology Challenges to Terrestrial Testing

Soft Error Effects on Integrated Circuits
- Single Event Upset
- Single Event Transient
- Single Event Functional Interrupt
- Test Results

Summary

Edward Petersen received his B.S. and M.S. degrees in physics from Oregon State in 1954 and 1956, and his Ph.D. in nuclear physics from UCLA in 1966. From 1963 through 1969, he taught at San Fernando Valley State College and Oberlin College. In 1969, he joined the Naval Research Laboratory (NRL) cyclotron branch as a research physicist. In 1980, he transferred to the NRL Radiation Effects branch, retiring in 1993. He has primarily studied single events with more than 30 publications in the area. In 1982 he presented an analysis of device threshold versus feature size that is still valid, and he developed the widely used Figure of Merit approach for upset rate calculations. He presented Single Event Tutorials at NSREC in 1983 and 1997. Dr. Petersen was awarded the IEEE NPSS Radiation Effects Award in 1998 and is an IEEE Fellow.

SOFT ERROR RESULTS ANALYSIS AND ERROR RATE PREDICTION

Edward Petersen
Consultant

Dr. Edward Petersen will discuss the analysis and use of various types of single event data. He will discuss how to examine for valid data. This will be followed by a discussion of the analysis and interpretation of various types of heavy ion data and how to interpret parametric studies of device sensitivity. The section will then discuss the various approaches to heavy ion and proton rate predictions for the space environment, and present a variety of sample calculations. The final portion will be a summary of the success of the predictions in various space experiments.

Introduction

Data Qualification and Analysis
- Illegitimate, Systematic, and Random Errors
- Samples of Problem Data – Rejection of Data
- Possible Problems with Fitting Data
- Geometrical and Other Adjustments to the Data

Analysis of Various Types of SEU Data
- Efficacy (Variation of SEU Sensitivity Within a Cell)
- Mixed Mode Simulations
- Parametric Studies of Device Sensitivity
- Single-Event Multiple-Bit Upset

Cosmic Ray Single Event Rate Calculations
- Introduction to Rate Prediction Methods
- The RPP Approach to Heavy Ion Upset Rates
- Effective Flux Approach
- Generalized Figure Of Merit

Proton Single Event Rate Calculations
- Semi-Empirical Approaches
- The Log Normal Distribution and the Proton Cross Section Curve
- Proton and Heavy Ion Upsets – Generalized Figure of Merit

Samples of Heavy Ion Rate Prediction
- Choosing Area and Depth for RPP Rate Calculations
- Geosynchronous Orbit
- SEE Sensitivity and the LET Threshold

Samples of Proton and Combined Environment Rate Prediction
- Circular, Elliptical and Ballistic Orbits
- Calculation of Combined Rates using the Figure of Merit

Samples of Solar Event Extreme Situations

Predictions and Observations Of SEU Rates In Space
- Results of Space Observations
- Constituents of a Good Rate Comparison Paper

Summary

Joseph M. Benedetto received his B.S. in Physics from the State University of New York and M.S.E.E. and Ph.D. degrees from the University of Maryland, College Park, MD. Dr. Benedetto began his career in radiation effects over 25 years ago as a Graduate Research Fellow at the National Bureau of Standards. In 1983 he joined the US Army's Harry Diamond Laboratories to work on hardening electronic components for strategic military systems and in 1995 he joined Aeroflex UTMC where he helped guide UTMC from a military components manufacturer with a dedicated fab to a "fab-independent" manufacturer of spacecraft electronics. His work included developing new methods for hardening and qualifying commercial integrated circuits for spaceborne applications. Dr. Benedetto is currently serving as Chief Technology Officer for Radiation Assured Devices, specializing in qualifying components for military and spaceborne applications. He has published over 75 technical articles in a wide variety of publications, including, IEEE Transactions on Nuclear Science, Journal of Applied Physics and IEEE Spectrum. To date he has been awarded three US Patents related to hardening spacecraft electronics.

SOFT ERROR CASE STUDY: SINGLE EVENT FUNCTIONAL INTERRUPTS (SEFIS) IN COTS SDRAMS

Joseph Benedetto
Radiation Assured Devices

Dr. Joseph Benedetto will present a case study in the evaluation of commercial memory circuits. Memory circuits are the subject of many soft error tests as they can sometimes dominate soft error rate predictions in a microelectronics system. Recent test results demonstrate the complexity involved in preparing for soft error testing as the observed failure modes are increasing. Additionally, memory devices are challenging to evaluate due to increasing speed of operation and increasing number of operating modes.

Introduction

Single Event Functional Interrupts (SEFIs) in Commercial SDRAMs Currently In Space Systems

- Initial SEFI Definitions
- Measuring SEFIs During Heavy Ion Beam Testing
- Expanded SEFI Definitions
- SEFI Error Rates with Increasing Memory Density
- Improving Error Rates via Operating Conditions

Distinguishing Between Single Event Latchup and SEFI Events

- Device Current as a Function of Fluence
- Non-Power Cycle Register Resets
- Unrecoverable SEFIs
- Test Methodologies to Help Distinguish between SEL and SEFIs

SEFIs in Commercial DDR SDRAMs

- DDR Devices Add Additional Complexity
- High Speed Testing Requirement
- Unrecoverable SEFIs in Addition to Recoverable SEFIs
- Need to Test as Used in System

Summary

Jeff Wilkinson joined Medtronic, Inc. in 1983 and is now a Technical Fellow and Senior Principal R&D Engineer with the Cardiac Rhythm Device Technology group. He has worked in product development on a variety of internal and external medical devices. Since 1999 he has been a part of the Device Technology group, developing and adapting technologies to meet the unique challenges of the implanted medical device. This work has included microprocessor design, ultralow power DSP, implantable sensors, and high reliability non-volatile memory. Since 2003 he has concentrated on ionizing radiation effects with a particular emphasis on soft-errors in implanted devices. Mr. Wilkinson is a member of the AAAS, senior member of the IEEE and holds a B.A. degree in Mathematics, Physics and Computer Science from St. Olaf College. He holds 10 US and international patents related to implantable medical device design.

SOFT ERROR CASE STUDY: IMPLANTABLE DEFIBRILLATORS AND PACEMAKERS

Jeff Wilkinson
Medtronic, Inc.

Jeff Wilkinson will discuss the challenges in designing for soft errors in the ultralow power regime of implanted medical devices. Implanted electronic medical devices are required to operate reliably for many years using a non-renewable power source. Mr. Wilkinson will review the functions and operating requirements for implanted electronics emphasizing the particular case of a life-critical cardiac pacemaker. Error mitigation strategies that may be appropriate for this application will be presented and compared. Finally, some surprising results related to other radiation effects will be briefly discussed.

Introduction

Implanted Medical Devices
- Types of Devices
- Distribution of Patients and Therapies

Implanted Electronics
- Pacemakers
- Defibrillators
- Other Electronic Implants

Radiation Environment for an Implant
- Environmental
- IC Packaging
- Clinical Radiation

Unique Challenges for an Implant
- Ultralow Power
- Surgical Barrier
- Pre-implant Environment

Total Dose and Dose Rate Effects

Summary