

# **Failure Mechanisms and Reliability**

## **ENME 808Q Spring 2000**

Reliability is the ability of a product to properly function within specified performance limits, for a specified period of time, under the life cycle application conditions. By understanding reliability principles, you will be better prepared as an engineer to contribute to product development. When you complete this course you will have the fundamentals and skills in the field of reliability as it directly pertains to the design and the manufacture of electrical, mechanical, and electro-mechanical products. Specifically you will learn the:

1. Reliability concepts including failure distributions, reliability metrics, and redundancy as well as risk assessment, mitigation and management.
2. Techniques to design and manufacture electronic products with improved reliability, based on the study of root-cause failure mechanisms.
3. Techniques to assess failures along with methods to conduct failure analysis.
4. Skills to develop a reliability program.
5. Methods to design and implement accelerated testing.
6. Methods to understand the reliability issues associated with warranties, safety, regulatory requirements, and the law.

### **Instructors:**

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**Time & Place:** TTh 5:00-6:15, Room 3114 Martin Hall

**Office Hours:** TTh, 3:00 – 5:00 pm. You are welcome to drop by our office anytime. Calling in advance is suggested. Questions raised due to skipping the class should be avoided.

**Expectations of Students:**

**Attendance:** Sitting-in or auditing this class is not normally permitted. Attending all classes generally leads to good grades.

**Communication Style:** No question is dumb. Ask your questions when they occur to you.

<b>Grading Process:</b>	Homework	10%
	Project	20%
	Mid-term	30%
	Final	40%

**Project Report Format:**

Word on Windows platform

Single Spaced Times Roman 10 pts

Note: It is highly recommended that you start your projects (research and writing) immediately. I also recommend that you submit a sample of your report 3 weeks prior to the due date to obtain some feedback on your progress. Do spell check on everything you write or submit.

**Resources:****Books:**

Michael Pecht, Editor, Product Reliability, Maintainability, and Supportability Handbook, ARINC Research Corp., CRC Press, Boca Raton, FL, 1995. [TK7870.P748 – UMCP]

Patrick D. T. O'Connor, David Newton, Richard Bromley, Practical Reliability Engineering, John Wiley & Sons, New York, NY, 1996. [TS173.O29 – UMCP]

Wayne Nelson, Applied Life Data Analysis, John Wiley & Sons, New York, NY, 1982. [TS173.N44 – UMCP]

Michael G. Pecht, Riko Radojcic, Gopal Rao, Guidebook for managing silicon chip reliability, CRC Press, Boca Raton, FL, 1999. [TK7874.P425 – UMCP]

Jerome Klion, Practical electronic reliability engineering: getting the job done from requirement through acceptance, Van Nostrand Reinhold, New York, NY, 1992. [TK7870.K554 – UMCP]

Milton Ohring, Reliability and failure of electronic materials and devices, Academic Press San Diego, CA, 1998. [TK7870.23.O37 – UMCP]

Puligandla Viswanadham, Pratap Singh, Failure modes and mechanisms in electronic packages, Chapman & Hall: International Thomson Pub./Thomson Science, New York, NY, 1998. [TK7870.15.V57 – UMCP]

Amerasekera, E. Ajith and Farid N. Najm. 1997. Failure Mechanisms in Semiconductor Devices, Second Edition. John Wiley & Sons: West Sussex. [TK7871.852.A47 – UMCP]

Lewis, E. E., Introduction to Reliability Engineering, John Wiley and Sons, Inc., New York, NY, 1996.

**Journals:**

Microelectronics Reliability [TK7870.E56 - UMCP]

IEEE Transactions on Reliability [TK7800.I16 - UMCP]

International Journal of Quality and Reliability [ENGIN STACKS – UMCP]

Reliability Engineering & System Safety [ENGIN CURPER – UMCP]

**Conferences:**

International Reliability Physics Symposium [TK7870.R45 - UMCP]

Annual Reliability and Maintainability Symposium [TA168.S856 - UMCP]

The books will be put in the Engineering library reserves during the course of the semester. The class notes will also be on the web.

# Course Outline

- 1 **The role of reliability engineering in today's world:** This session provides motivation for reliability functions within the framework of technical innovation, product development, and economic, social, and legal practices.
- 2 **Reliability concepts and applicability:** This session presents the fundamental reliability concepts and methods needed to design and to assess products in a timely and cost-effective manner. Measures of reliability, such as hazard rate, failure probability density distribution, useful life, conditional reliability and failure-free operating period are discussed.
  - Statistical concepts and distributions
  - Metrics for reliability
  - System reliability modeling
- 3 **Assessment of root-cause failure mechanisms**
  - Life cycle loads
  - Stress analysis
  - Failure mechanisms, modes, and sites
  - Overstress and cumulative-damage mechanisms
  - Damage models
- 4 **Validation, qualification, and quality assurance:** This session presents the various types of screens and tests, including acceleration methods, environmental stress screening (ESS) methods, design verification, step stress, HALT, STRIFE, HASS, and others. This session shows how and when to use each type of test, and how to evaluate and eliminate unnecessary testing and screening. Methods to relate accelerated test data to field reliability are discussed.
  - Accelerating wearout failure mechanisms
  - Proof-testing overstress mechanisms
  - Interactions between different stress environments
  - Tailoring the test parameters for best results
  - Stress margins for overstress mechanisms
  - Acceleration transforms for wearout mechanisms
  - Quantifying damage caused by quality assurance testing
- 5 **Reliability design techniques**
  - Failure modes and effects analysis
    - Evaluation of potential impacts of failures
    - Analysis of potential impacts
  - Sneak circuit analysis
    - Application
    - Minimizing occurrences
  - The stress-strength interference concept
    - Designed-in strength versus operational stress
    - Mean stress and strength versus the extreme stresses and strength
    - Strategies for reducing part strength variabilities
- 6 **Variability analysis techniques**
  - Sensitivity analysis
    - Effects of variations on reliability
      - Design variations
      - Material variations
      - Manufacturing variations
      - Operational variations
    - Sensitivity interactions
  - Worst case analysis

- 7      **Reliability assessment methodologies**
- Empirical and physics based methodologies
  - Assessing and comparing reliability assessment methodologies
  - Reliability standards
  - Reliability assessment software tools
  - Application specific reliability assessment
- 8      **Risk assessment, mitigation and management**
- Product development cycle and time-to-market
  - Supply-chain management: qualified vendors
  - In-situ health monitoring using sensors and early-warning fuses
  - Assessing remaining life
  - Eliminating 'Could Not Duplicate' problems
  - Obsolescence cycles and time-in-market
  - Warranties
  - Safety
  - Regulatory requirements
  - Legal issues
- 9      **Failure analysis methods**
- Specimen preparation
    - Initial examination and preparation
    - Cross-sectioning
    - Decapsulation of plastic packages
    - Delidding ceramic and metal case packages
  - Measurement techniques
    - Optical microscopy
    - Environmental scanning electron microscopy
    - X-ray radiography
    - Acoustic microscopy
    - X-Ray spectroscopy
    - Wire pull, ball bond, die and solder ball shear testing
    - Focused ion beam
    - Superconducting quantum interface device microscope