COURSE: ECE730/QIC890-T33

COURSE TITLE: **Introduction to Noise Processes : Classical and Quantum Devices**

INSTRUCTOR: Prof. Na Young Kim
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Note: Do not use LEARN email to reach the instructor

LECTURES: [redacted]

DESCRIPTION

The course will introduce fundamentals of various noise processes in classical and quantum devices. Review of mathematical methods in classical and quantum statistical mechanics is given, on which the theoretical framework of noise processes is developed. Thermal, shot, *1/f* and quantum noise processes are studied in macroscopic and mesoscopic electrical and optical devices. We discuss measurement techniques of noise processes and the meanings of measurement accuracy. We introduce machine learning algorithms in the context of statistical perspectives.

COURSE OBJECTIVE

The course is designed for students to

- Review classical and quantum statistical mechanics and learn mathematical framework to describe noise processes;
- Understand thermal, shot, *1/f* and quantum noise processes in devices;
- Study coherence and decoherence processes and control effects.

Expected Background: Basic understanding of statistical mechanics, quantum mechanics, solid-state electronics, photonics devices and strong calculus is required.

SYLLABUS

I. **PART 1: Theoretical Foundations** (3 weeks)

1. Classical Probability Theory
   - Time vs Ensemble Average
   - Ergodic Proceses
   - Statistically Stationary *vs* Non-stationary Processes
   - Parseval, Energy, Wiener-Khintchine, Carson Theorems
   - Power Spectral Density
   - Basic Stochastic Processes
2. Principles of Quantum Statistics
   - Basic Stochastic Processes
   - Fluctuation-Dissipation Theorem
   - Symmetrization, Non-Commutability Postulates
   - Thermodynamic Partition Functions
   - Equipartition Theorem

II. **PART 2: Stochastic Processes in Devices** (4 weeks)

3. Types of Noises
   - Thermal Noise
   - Shot Noise
   - $1/f$ Noise
   - Quantum Noise

4. Classical and Quantum Circuit Theory
    - Two- and Four-terminal Networks
    - Noise Figures of linear circuits and cascaded circuits
    - Fluctuation-Dissipation Theorem
5. Show Case 1: *p-n* Junction Devices
6. Show Case 2: superconducting Devices

III. **PART 3: Advanced Topics** (4 weeks)

7. Stochastic Differential Equations
8. Measurements and Feedback Control
9. Noise Analysis of Quantum Hardwares

TEXTBOOK

None required. Article handouts provided and lecture notes will supplement course lectures.

COURSE WEBSITE

The course homepage is on LEARN, where course syllabus, lecture notes and problem sets are uploaded. Any important updates will be announced as well.

GRADE DISTRIBUTION

- 4 **Problem Sets :** 40%

  Problem Set Late Policy

  $S(t) = S(0)*(10-t)*0.1$ if $t < t_s$ or $S(t) = 0$ if $t > t_s$,

  where $t = 0$ is the due date, t is the turn-in date, and t_s is the solution posting date.

  Exception to this policy can be made in special circumstances by contacting the instructor in advance. Note that any evidence violating Honor code (e.g. plagiarism, copying and etc.) will yield $S(t) = 0$ regardless of t.
- **Mid-term Presentation**: 10%
- **Final : 50%**
    - **Final Oral Presentation:** 25%
    - **Final Term Paper:** 25%