Northeastern
College of Engineering

TELE 6550: IoT Embedded System Design

FALL 2025

Course Information
Course Title: IoT Embedded System Design
Course Number: TELE 6550
Term and Year: Fall 2025
Credit Hour: 4
CRN: 17764
Course Format: Traditional

Instructor Information
Full Name: Haitham Tayyar
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Office Hours: Click or tap here to enter text.

Instructor Biography
Dr. Haitham Tayyar holds a PhD in Electrical Engineering from the University of British Columbia in Vancouver. He has over 18 years of experience working at various academic institutions across the world in the fields of Electrical Engineering, Computer Engineering, and Information Technology. In his professional career, Dr. Tayyar worked as a software engineer, a micro-electronics failure analyst, as well as a telecommunications engineer.

Teaching Assistant Information
Full Name: Click or tap here to enter text.
Email Address:Click or tap here to enter text.
Office Hours:

Course Prerequisites
None

Course Description
This class explores the technologies and techniques behind the evergrowing field of design and development of embedded/smart devices in Cyber-Physical Systems. Specifically, it focuses on a hands-on approach based on the ESP32 embedded software development. It first introduces different instruction set architectures to transition to C C++ and C++11 development and debugging. It applies theoretical concepts to practical issues affecting embedded systems including processor pipelining, parallelism and concurrency, memory architectures as well as input and output interfaces (GPIO, I2C, UART, SPI). Discusses applications ranging from signal

processing to physical system interaction with IoT assets. Presents bare-metal and FreeRTOS based development with focus on multitasking, scheduling, interrupts, threads, processes, tasks, inter process communication, contention, drivers, semaphores, mutexes and shared memory. Serves as the foundation for the Advanced class on Embedded Development.

Course Learning Outcomes

At the completion of this course, students will be able to:

1. Identify components of IoT embedded systems
2. Know basic concepts of IoT embedded device design
3. Understand hardware/software mechanisms for sensing and actuation on IoT embedded devices

Required Tools and Course Textbooks.

No Required Text

Recommended Text(s):

1. "FreeRTOS Documentation", https://github.com/FreeRTOS/FreeRTOS-Kernel-Book/releases/download/V1.1.0/Mastering-the-FreeRTOS-Real-Time-Kernel.v1.1.0.pdf; 2024
2. "ESP-IDF Programming", https://docs.espressif.com/projects/esp-idf/en/stable/esp32/index.html; 2024
3. "Introduction to Embedded Systems - A Cyber-Physical Systems Approach", E. A. Lee and S. A. Seshia, 2nd Edition, MIT Press; 2017
4. "Cyber-Physical Systems", R. Rajkumar, D. de Niz and M. Klein, 1st Edition, Addison-Wesley; 2017
5. "Real-time Operating Systems: Book 1", J. Cooling, 2nd Edition, Lindentree Assoc; 2019
6. "Embedded Software for the IoT: The Basics, Best Practices and Technologies", K. Elk, 2nd Edition, CreateSpace Independent Publishing Platform; 2017
7. "Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems, and the Internet of Things", P.Marwedel, 3rd Edition,Springer; 2018
8. "Fundamentals of IoT Communication Technologies", R. Herrero, 1th Edition, Springer-Nature; 2021
9. "C Programming Absolute Beginner's Guide: C Progr Absol Begin Guide", G. Perry, D. Miller, 3rd Edition, Que; 2013
10. "Effective Modern C++", S. Meyers, 1st Edition, Que; 2014

Course Schedule/Topics Covered.

Week	Date	In Class Topic	Assignment Due
1	**09/02**	• Embedded Systems Concepts [2][6] – IoT and CPS components – Embedded Device Design Challenges (Power and Computational Constrains) • C Programming on ESP32 – ESP32 Device – Logical operators, binary, hex and decimal arithmetic – Data Types, Variables, Constants and Literals, Storage, Decision Making	
2	**09/9**	• REVIEW Embedded Devices Signal Concepts [1][5] – Range, Dynamic Range, Quantization – Noise, Sampling, Harmonic Distortion, Signal Conditioning – Use cases: Temperature Sensor, Engine Speed Control Actuator • C Programming on ESP32 – Loops, Functions, Scopes, Arrays, Pointers, Strings	
3	**09/16**	• REVIEW Embedded Devices Machine Learning [1][5] – ML and TinyML • C Programming on ESP32 – Structures, Unions, Bit fields, Typedef, I/O	
4	**09/23**	• Theoretical Background (State Machines) [1] – Finite and Extended State Machines • Classic C++ Programming – Streams, inheritance, polymorphism, rule of three, operators, templates.	
5	**09/30**	. Theoretical Background (State Machines) [1] – Theoretical Background (Concurrent Computation): – Models, Synchronous Reactive Computation - . ARMv7 Assembler Programming	
6	**10/7**	• Hardware: Embedded Processors [1][2][3] – General Purpose vs Embedded Processors; Microcontrollers, DSPs, GPUs – Parallelism vs Concurrency, Pipelining – Instruction Level Parallelism – Multiprocessor/Multicore Systems • Modern C++ Programming – Smart pointers, lambda functions, right side references.	
7	**10/14**	• Hardware: Memory Architectures [1][3]	

		– Memory Technologies; RAM vs non-volatile – Memory Maps; Register Files; Scratchpads and Caches – Addresses; Stacks; Memory Protection Units – Dynamic Memory Allocation – Usage and Management • ESP32 Memory Management	
8	**10/21**	• Hardware: Input and Output [1] – IoT/CPS I/O Technologies – I/O Hardware; PWM, GPIO, Serial (UART, SPI, I2C, SDIO), Parallel, JTAG/SWD – Sequential Software in Concurrent Schemes – Interrupts and Exception, Atomicity, Interrupt Controllers • ESP32 I/Os	
9	**10/28**	• Midterm Exam	
10	**11/4**	• OS Basic Concepts [1][3][4] – Multitasking; Imperative Programs – Threads; Creating/Implementing Threads, Mutexes, Semaphores, Deadlocks – Memory Consistency Models – Tasks; Task Priorities; Intertask Communication – Messages, Queues, Mailboxes • FreeRTOS ESP32 Basics	
11	**11/11**	• OS Scheduling [1][3][4] – Scheduling Policy; Scheduler Implementation – Rate Monotonic Scheduling, EDF – Scheduling and Mutual Exclusion – Priority Inversion, Priority Inheritance Protocol; Priority Ceiling Protocol – Multiprocessor Scheduling • FreeRTOS ESP32 Multitasking	
12	**11/18**	• OS Advanced [3][4] – Strictly polling, RTOS vs GPOS • FreeRTOS ESP32 I/Os	
13	**11/25**	NO CLASS (Thanksgiving/Fall Break Recess)	
14	**12/2**	• OS Advanced [3][4] • FreeRTOS ESP32 Communications • Class Project Due	

Assignment Grading

- Labs/Assignments 40%
- Project 20%
- Quizzes 10%
- Midterm Exam 15%
- Final Exam 15%

Grading Scale

	87-89.9% B+	77-79.9% C+	
95-100% A	84-86.9% B	74-76.9% C	
90-94.9% A-	80-83.9%B-	70-73.9% C-	69.9% or below F

Attendance/Late Work Policy

Attendance Policy

Students registered in MGEN courses (INFO, CSYE, and DAMG) are allowed **a maximum of 2 absences per course, with 3 or more absences resulting in an automatic 'F' for that course.** Students are expected to inform their instructors of any absences in advance of the class; if a student is sick long-term or experiences a medical issue that prevents class attendance, it is strongly encouraged that they speak with their Academic Advisor (coe-mgen-gradadvising@northeastern.edu) to learn more about the Medical Leave of Absence. Should a student anticipate being unable to attend 3 or more classes, they should discuss their situation with their Academic Advisor to explore other types of leave in accordance with the University's academic and global entry expectations. International students should review the Office of Global Services webpage to understand their visa compliance requirements.

Teaching Assistants (TAs) or Instructional Assistants (IAs) will be present at each class to collect student attendance.

Late Work Policy

Students must submit assignments by the deadline in the time zone noted in the syllabus. Students must communicate with the faculty prior to the deadline if they anticipate work will be submitted late. Work submitted late without prior communication with faculty will not be graded.

End-of-Course Evaluation Surveys

Your feedback regarding your educational experience in this class is particularly important to the College of Engineering. Your comments will make a difference in the future planning and presentation of our curriculum.

At the end of this course, please take the time to complete the evaluation survey at **https://neu.evaluationkit.com**. Your survey responses are **completely anonymous and confidential**. For courses 6 weeks in length or shorter, surveys will be open one week prior to the end of the courses; for courses greater than 6 weeks in length, surveys will be open for two weeks. An email will be sent to your Northeastern University Mail account notifying you when surveys are available.

Academic Integrity

A commitment to the principles of academic integrity is essential to the mission of Northeastern University. The promotion of independent and original scholarship ensures that students derive the most

from their educational experience and their pursuit of knowledge. Academic dishonesty violates the most fundamental values of an intellectual community and undermines the achievements of the entire University.

As members of the academic community, students must become familiar with their rights and responsibilities. In each course, they are responsible for knowing the requirements and restrictions regarding research and writing, examinations of whatever kind, collaborative work, the use of study aids, the appropriateness of assistance, and other issues. Students are responsible for learning the conventions of documentation and acknowledgment of sources in their fields. Northeastern University expects students to complete all examinations, tests, papers, creative projects, and assignments of any kind according to the highest ethical standards, as set forth either explicitly or implicitly in this Code or by the direction of instructors.

Go to http://www.northeastern.edu/osccr/academic-integrity-policy/ to access the full academic integrity policy.

MGEN Student Feedback
Students who would like to provide the MGEN unit with anonymous feedback on this particular course, Teaching Assistants, Instructional Assistants, professors, or to provide general feedback regarding their program, may do so using this survey: https://neu.co1.qualtrics.com/jfe/form/SV_cTlAbH7ZRaaw0Ki

University Health and Counseling Services
As a student enrolled in this course, you are fully responsible for assignments, work, and course materials as outlined in this syllabus and in the classroom. Over the course of the semester if you experience any health issues, please contact UHCS.

For more information, visit https://www.northeastern.edu/uhcs.

Student Accommodations
Northeastern University and the Disability Resource Center (DRC) are committed to providing disability services that enable students who qualify under Section 504 of the Rehabilitation Act and the Americans with Disabilities Act Amendments Act (ADAAA) to participate fully in the activities of the university. To receive accommodations through the DRC, students must provide appropriate documentation that demonstrates a current substantially limiting disability.

For more information, visit https://drc.sites.northeastern.edu.

Library Services
The Northeastern University Library is at the hub of campus intellectual life. Resources include over 900,000 print volumes, 206,500 e-books, and 70,225 electronic journals.

For more information and for education specific resources, visit https://library.northeastern.edu
Network Campus Library Services: Northeastern University Library Global Campus Portals

24/7 Canvas Technical Help
For immediate technical support for Canvas, call 617-373-4357 or email help@northeastern.edu

Canvas Student Resources: https://canvas.northeastern.edu/student-resources/

For assistance with my Northeastern e-mail, and basic technical support:
Visit ITS at https://its.northeastern.edu
Email: help@northeastern.edu
ITS Customer Service Desk: 617-373-4357

Diversity and Inclusion
Northeastern University is committed to equal opportunity, affirmative action, diversity, and social justice while building a climate of inclusion on and beyond campus. In the classroom, members of the University community work to cultivate an inclusive environment that denounces discrimination through innovation, collaboration, and an awareness of global perspectives on social justice.

Please visit http://www.northeastern.edu/oidi/ for complete information on Diversity and Inclusion

Title IX
Title IX of the Education Amendments of 1972 protects individuals from sex or gender-based discrimination, including discrimination based on gender-identity, in educational programs and activities that receive federal financial assistance.

Northeastern's Title IX Policy prohibits Prohibited Offenses, which are defined as sexual harassment, sexual assault, relationship or domestic violence, and stalking. The Title IX Policy applies to the entire community, including male, female, transgender students, faculty, and staff.

In case of an emergency, please call 911.

*Please visit **https://www.northeastern.edu/ouec** for a complete list of reporting options and resources both on- and off-campus*.