Class Syllabus

Personnel

Instructor: Dr. Mark Palmeri

- Email: (mark.palmeri@duke.edu)[1]
- Office Hours: `http://meet.palmeri.io`
  - 258 Hudson Hall Annex
  - `https://duke.zoom.us/my/mark.palmeri`

Lab Master: Matt Brown (matt.brown@duke.edu)

Teaching Assistants:

- Rebecca Hogewood (rebecca.hogewood@duke.edu)
- Ayush Shetty (ayush.shetty@duke.edu)

Course Times & Locations

Lecture: Mon & Wed from 08:30–09:45 in Wilkinson 136

Lab: Fri from 08:30–11:30 in 5704 Chesterfield (Design Suite) [2]

Course Objectives

This course will give students experience with the design, function and deployment of medical electrical equipment. Students will have hands on experience with electronic hardware and software development, along with gaining experience with biosignal transduction into circuits.

Upon completion of this course, students should be able to:

- Transduce electronic biosignals
- Develop firmware using Zephyr as a bare-metal super-loop and a Realtime Operating System (RTOS)
- Embed firmware on the Nordic `nRF52833 DK`, including ADC, PWM, timers and BLE.
- Version control software / firmware development using (`git`)
- Utilize callbacks / interupt service routines for realtime event detection and response.
- Perform electronics schematic capture, using heirarchcal sheets.
- Layout single- and double-sided printed circuit boards.
- Know what traces, cabling and connectors to use for power and signals.
- Make design choices between AC and battery power sources.
- Use different data encoding and communication protocols, including UART, I2C, SPI, and BLE
- Outline procedures to adhere to relevant industry and safety standards (e.g., UL, IEC60601, IEC62304) for FDA 510k clearance.

[1] Response time will be way faster via Teams!

[2] A campus shuttle runs to/from the E-quad; details can be found here: `https://parking.duke.edu/buses/downtown-shuttle`.

Prerequisites

- Introductory Circuit Analysis (ECE110 or equivalent)
- Medical Software Design (recommended, BME547 or equivalent experience [`git` and `C`])
- Instrumentation / Mechatronics (recommended)

Resources

Hardware

The following development kit is **required** hardware for this semester: nRF52833 DK

Textbooks

All of these books contain valuable content and will be referenced throughout the semester. If you are looking to pursue a career in medical device design, then it may be worth having one of these as a reference.

- Practical Electronics for Inventors (Scherz & Monk) [Fourth Edition]
- The Art of Electronics (Horowitz & Hill) [Third Edition]
- Design of Biomedical Devices and Systems (King, Fries, Johnson)
- Product Design and Development (Ulrich, Eppinger)
- Design of Biomedical Devices and Systems, King, Fries & Johnson

Online Resources

We will be using the following [E]CAD packages:

- KiCad[3][4]

These are cloud tools or cross-platform for installation on your personal computers.

- Teams - "Slack-like" tool for live chat, team discussion, asking questions and resource sharing
- diagrams.net - software / hardware flowcharts, functional decomposition
- Visual Studio Code - supported IDE for Nordic nRF Connect tools
- Git - version control software
- GitLab - version control / project mangement
- Zephyr Project Documentation
- nRF Connect SDK Fundamentals

[3] Please download and install the stable version (currently `v6.0.10`). Do not install the `v7.x` release candidate!
[4] If you know Altium Designer, you are welcome to use it instead, but the class will only support KiCad.

Attendance & Participation

Class participation, including lecture attendance, team meetings, and scheduled lab time, contributes to your class grade. Not being able to participate in class activities due to illness should be reported using the Short Term Illness Form (STIF) **before** the missed class activity.

If you have a non-illness-related reason for not being able participate in a class activity or meet an assignment submission deadline, please reach out to Dr. Palmeri as soon as possible to discuss the situation.

Students are responsible for obtaining missed lecture content from other students in the class. Lectures will be recorded via Panopto and available via Sakai.

Class Schedule

The following table is an overview of activities this semester (always use Gradescope for the latest information on assignment due dates).

MONDAY	WEDNESDAY	FRIDAY
Jan 9th **1**	11th **2** Syllabus Review & Software Installations	13th **3** **Lab:** Personal Laptop Software Installation & Configuration
16th MLK Holiday (No Class)	18th **4** ECAD: Schematic Capture	20th **5** **Lab:** KiCad Schematic Capture
23rd **6** ECAD: PCB Layout	25th **7** ECAD: PCB Layout	27th **8** **Lab:** KiCad PCB Layout
30th **9** Digital Data Encoding & Logic	Feb 1st **10** ADC and DAC	3rd **11** **Lab:** ADC & Data Encoding
6th **12** Instrumentation: Amplification & Level Shifting	8th **13** Instrumentation: Filtering & Rectification	10th **14** **Lab:** Circuit Design: Instrumentation
13th **15** Circuit Design Review; PCB Layout (`nRF52833DK` "shield"; DK Overview)	15th **16** Crash Course in C	17th **17** **Lab:** Instrumentation Design: PCB Layout; Nordic Dev Academy
20th **18** Zephyr: Devicetree & GPIO	22nd **19** Zephyr: Callbacks	24th **20** **Lab:** Zephyr: GPIO & Callbacks Firmware

MONDAY	WEDNESDAY	FRIDAY
27th **21** Zephyr: Logging, Debugging with JTAG	Mar 1st **22** Zephyr: Timers	3rd **23** **Lab:** Zephyr: Timers
6th **24** Zephyr: SAADC	8th **25** SAADC	10th **26** **Lab:** SAADC
13th Spring Break (No Class)	15th Spring Break (No Class)	17th Spring Break (No Class)
20th **27** Zephyr: PWM	22nd **28** PWM DAC	24th **29** **Lab:** ADC (Internal & VDD References)
27th **30** Serial Communication: UART, I2C, SPI & beyond	29th **31** Firmware Worktime	31st **32** **Lab:** PWM DAC (DC, Sawtooth, Sinusoid)
Apr 3rd **33** Final Project Overview	5th **34** Final Project: Differential ADC, Sampling Buffers, RMS Averaging Algorithms	7th **35** **Lab:** Final Project (Differential SAADC)
10th **36** Bluetooth Low Energy (BLE)	12th **37** BLE: GATT / Custom Services / Notifications	14th **38** **Lab:** Final Project (BLE)
17th **39** AC Power: Circuit Breakers, Polarity, Grounding, Shock Risk Reduction	19th **40** Battery Power: Battery Types, Voltage Regulation, Li-Ion Recharging Considerations	21st **41**

Final Project Due: April 26, 2023 at 17:00

Grading

The following grading scheme will be used for this course:

Participation	15%
Midterm Projects & Deliverables	50%
Final Project Report	35%

Final Course Grades

This course is not "curved" (i.e., a distribution of grades will not be enforced), and a traditional grading scheme will be used (e.g., 90-93 = A-, 94-97 = A, 97-100 = A+).

Failing the course can happen with a cummulative score < 65 or not completing all of the assignments.

All grades will be posted to Gradescope throughout the semester to track your performance.

Gradescope

All graded assignments, associated due dates (usually Fridays at 17:00), and grades/feedback will be posted on Gradescope. Regrades must be submitted via Gradescope.

- **You must associate the pages of your submission with the grading rubric criteria during the submission process.** Failure to do so will result in lost assignment credit.
- For team submissions, please make sure that assignments have **each team member associated with the submission**.

Late Policy

Permission to submit an assignment late should be sought from Dr. Palmeri as far in advance as reasonably possible, but no less than 48 hours in advance, except in cases of illness.

Unexcused late assignments will lose 50% of their potential point value for each 24 hour period beyond the due date (i.e., 100% $\rightarrow$50% $\rightarrow$ 25%...).

All assignments must be satisfactorily completed by each student to pass the class, even if no credit will be awarded based on the late policy.

Regrades

Any regrading requests need to be made via Gradescope within one week of grades for a given assignment being returned using Gradescope. You must provide a description of why you feel a regrade is appropriate. Requesting a regrade could lead to additional loss of credit when an assignment is re-evaluated.

There will be a combination of individual and team-graded assignments. Some assignments will have an opportunity to be resubmitted based on grading feedback at the discretion of Dr. Palmeri.

Duke Community Standard & Academic Honor

Engineering is inherently a collaborative field, and in this class, you are encouraged to work collaboratively on your projects. The work that you submit must be the product of your and your group's effort and understanding. All resources developed by another person or company, and used in your project, must be properly acknowledged.

All students are expected to adhere to all principles of the Duke Community Standard. Violations of the Duke Community Standard will be referred immediately to the Office of Student Conduct. Please do not hesitate to talk with Dr. Palmeri about any situations involving academic honor, especially if it is ambiguous what should be done.