EE 6435: Neuromorphic Analog VLSI Circuits
Spring 2022 Semester
Time: T Th 3:30pm – 4:45pm
Course Site http://hasler.ece.gatech.edu/Courses/ECE6435/index.html

Professor
Professor Jennifer Hasler, jennifer.hasler@ece.gatech.edu
Office Hours: T Th 3:00-3:30pm, 4:45p – 6:00pm
Afolabi Ige,
Pranav Mathews

Objectives

- To have an understanding of analog circuit design, computational neuroscience, and the common properties between these two efforts.
- To understand the historical background around neuromorphic and physical computing systems
- To design neuromorphic and physical computing circuits and systems
- To critically evaluate current and past neuromorphic computing and physical computing efforts

Course Grading

Your course grade will be based on your performance on projects based on experimental data, design projects based on this data, maybe some short in-class exercises, and a final project or report.

Grade Computation: Your course grade will be based on your performance on your projects and your final project by the following percentages:

	Design Projects	Final Paper / Project
% of Final Grade	70%	30%

I am personally hoping that the need for any exams is not needed. That includes that all students work hard to learn the material, so that individual evaluations are not necessary. In the case that I find such measurement instruments necessary for this class, I reserve the right to add such exams to the course.

Design Projects: A key part of the Analog IC design, and in particular Neuromorphic Analog VLSI design, experience is the electrical measurements of integrated circuits. We do not want this class to degenerate into a theoretical discussion about circuit analysis. The projects center on experiments to be performed on custom VLSI chips that were built especially for this class. Projects will be done in groups, typically groups of *two*. Projects will consist of analytical problems and design problems. We will be finished with these design projects by the start of spring break, so everyone gets a *break* from the class.

These projects will involve experimental data from FPAA boards, and are well-developed exercises from previous year's projects as well as some new projects. The projects center on experiments to be compiled and measured on custom Field Programmable Analog Arrays (FPAA) that have been invented at Georgia Tech after many years of research into analog circuit and signal processing. All of these projects are designed to give the necessary data, circuit experience, and FPAA experience needed to be successful in the design projects. Therefore, to do well on the design projects, you need to complete this material. Each of the projects starts with example blocks that are known to robustly work. Most of the remaining experimental projects involve modifying these starting diagrams for that week's project. Experimental data should be processed in Scilab (MATLAB is acceptable for the final plots).

Final Project: The final project will either be a design project (group) or a final paper critically analyzing an area of physical computing / neuromorphic engineering (individual).

General Course Information and Policies

Attendance: Students are responsible for all material covered in class, including changes in project schedules announced in class. The easiest way to do poorly in my class is to skip class or not pay attention while in class; conversely, paying attention to class material strongly correlates with higher grades. Further, I will not take up class time to review information that students have missed because of being excessively late.

Prerequisite material: It is assumed that most students do not have a strong background in all of computing, analog circuits, and neuroscience. We design this course to have mostly self-consistent lectures and material. We have to assume some basic starting points for the class so we can develop strength in these areas. We do expect as prerequisite material some knowledge of transistor circuits (e.g. ECE 3400 and/or ECE 4430 and/or equivalent), as well as fluency in spoken and written English.

Academic Honesty: Although students are encouraged strongly to work together to learn the course material, all students are expected to complete projects (in the respective groups) individually, following all instructions. You may discuss project questions in large groups, but each group must independently perform and write-up the required work for each project. All conduct in this course will be governed by the Georgia Tech honor code. Additionally, it is expected that students will respect their peers and the instructor such that no one takes unfair advantage of anyone else associated with the course. Any suspected cases of academic dishonesty will be reported to the Dean of Students for further action.

Project Policies

*Project handouts***:** Project handouts will be available on the web. The project topic will closely correspond to the lecture topic for that week period.

*Working in groups of two***:** You will work on your projects in groups of two. To forms these groups, I am giving you two options. First, you can choose grouping on your own. Second, I can choose a partner for you. You may change partners between projects, but not during an individual project. I will probably change partner groups before spring break some point, at least once. The final project could be a larger group. I reserve the right to assign these groups. If you choose to go alone, I will not make any concessions, but if your partner drops in the middle of a project, then I will take into account you may discuss the questions in large groups, but each group must independently perform and write-up the required work.

Each Student has a Laptop: Remember GT policy is that everyone has a laptop (MAC, PC, or Linux) of a given capability. You will need it throughout this semester.

*Experiments***:** A key part of the Analog IC design, and in particular Neuromorphic Analog VLSI design, experience is the electrical measurements of integrated circuits. We do not want this class to degenerate into a theoretical discussion about circuit analysis. The projects center on experiments to be performed on custom VLSI chips that were built especially for this class. Further, you will have the unique opportunity to have an analog IC design experience where you will be able to experimentally measure and verify your designs. We require that each group bring in your laptop computer to class. In the past, our approach was using MATLAB as our primary testing engine as well as data analysis, and we had to figure out how to make sure everyone had a working setup with multiple moving parts. Now, we have a new (and improved) set of tools, based on our experience in MATLAB / Simulink, built on scilab / scicos / Xcos, which is an open source, nearly code compatible, version of MATLAB / Simulink. If you want to generate final data plots in MATLAB, you are welcome to do so.
Therefore, we require that everyone has VirtualBox (https://www.virtualbox.org/, and you need the extensions file) as well as have loaded our current version of our Ubuntu virtual machine. You can download the VM (4GB file) from http://users.ece.gatech.edu/phasler/FPAAtool/index.html. Since all of these approaches are available to everyone for free, we expect there will be no hardship for everyone to everything working well. We are using a virtual machine approach to simplify the installation of the resulting system required for testing, characterization, and measurement. If you have interest in running things directly in Ubuntu, we can work with you for the directions for that setup.

Experimental Setup: FPAA devices: This class will make use of experimental results on large-scale Field Programmable Analog Arrays (FPAA), innovated and developed primarily at GT. The entire test setup (for almost all cases) is a laptop computer (which each group will have), working virtual machine setup described above, and an FPAA board. Alot of the design and development can be done before having the board connected, particularly in the design phases, thereby allowing alot of flexibility for each student on completing the resulting assignments. We will be setting up student laptop setups during the first week of classes. We will start by having FPAA boards in class, and some experimental work might start in class as part of class. There is an opportunity to use the boards after class. We will allow boards to be checked out from our class location as long as they are kept in the building. We will have some lectures where we bring additional hardware. There is no need to show any code unless the project explicitly asks for it.

Project submission: we will require the following procedure that we will use to grade projects:

- **Deadlines are hard**: You need to complete all required items for the project, which will include analysis, experimental measurements, some system level modeling, and data analysis. Projects handed in after this deadline will not be accepted.
- **Project Writeup** : You will have one writeup, which must be word-processed, two-column IEEE format with data figures integrated into the text. You may not have your data figures added to the end of the writeup. You will submit the writeup as a .pdf file, and only as a .pdf file. You should integrate data and analysis together on your submitted plots. For example, if you perform a curve fit, I expect the curve fit and the

data to be on the same graph, where the data points would be in point markers (e.g. "o"), and the curve fit would be a straight line. The plots need to be MATLAB style plots (MATLAB, scilab, python MATLAB), and not other non-technical forms (e.g. Excel). Do not submit your MATLAB code to generate the plot. Your writeup is limited to 9 pages including references and figures. Submit only one writeup per group of two individuals. **Make sure both names are on the document**.

- ***Extensions on due dates will not be granted unless there is a very compelling reason*** (e.g., a medical problem by everyone in the team). To get an extension, you must talk with me before the due date.

Course Schedule

Lectures will closely correspond to the projects that we are working on that week.

Project Topic	**Project Due Date**
MOSFETs, Modeling, FPAA FPAA basics and Basic MOSFET Circuits	Jan 19
Continuous-Time Filters, Bandpass Filters, and Filter Banks	Feb 2
Neurons: Passive and Active Biological and Transistor Channels	Feb 16
Winner-Take-All (WTA) Circuits, Vector-Matrix Multiplication (VMM), and VMM+WTA Classifier	March 1
Networks of Neurons: SynFire Chain, WTAs, and CPGs	March 15
Spring Break (March 21-25)	Break
Final Critical Paper	April 19

Spring 2022 key dates:
Jan 9th, first day of class
Jan 15th (MLK day)
March 15 (last day before Spring break)
March 18-22, 2022: Spring Break
April 19: last day of normal class (4 weeks for final paper)