

**ASEN 6091 / ECEN 5014**  
**Global Navigation Satellite System (GNSS) Receiver Architectures**

**Fall Semester 2022**  
**Lecture Times: TTH 01:00 PM - 02:15 PM**

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### **Course Overview**

GNSS is a generic term describing the expanding field of satellite-based navigation/timing systems. The most prevalent of these systems currently is GPS which is owned and operated by the US. However, Russia maintains a system known as GLONASS. Both the European Union and China are developing their own GNSS system designated Galileo and Beidou (Compass), respectively. Lastly, there are a number of regional GNSS augmentation systems including but not limited to: WAAS (US), QZSS (Japan), EGNOS (EU), India (GAGAN) each of which provides GNSS corrections and, in some cases, ranging information.

There are a multitude of GPS receivers on the market today. Often times these receivers are embedded for monitoring and control and often, unfortunately, treated as a "black box". This course goes into the inner workings of a GPS receiver and also discusses features common to all GNSS receivers. The course will cover the analog radio frequency conditioning from the antenna to the analog-to-digital converter, then focus on the various signal processing algorithms used in GNSS receiver (acquisition, code tracking, carrier tracking, and navigation data decoding), as well as present the position/time solution. Such treatment of the operation of the receiver will provide insight into the trade-offs that go into GNSS receiver design.

The GNSS receiver is a specialized Code Division Multiple Access (CDMA) spread spectrum receiver. Thus those interested in CDMA technology will benefit from a "hands on" perspective and gain insight into the specifics of CDMA receivers designed for navigation and timing functionality.

Students interested in the course will be required to have a solid background in using Matlab. Some knowledge in signal processing, particular time/frequency domain transforms, and control theory would be helpful. Lastly, background on GPS or GNSS in general (such as ASEN 5090) is expected, but not required, and will definitely aid in the overall understanding of the technology.

### **Course Format**

The course will follow a blend of traditional lectures with external independent lab/computing assignments. The traditional lectures will provide the basics of low-level GPS signal processing building on the internal operation of a GNSS receiver. Comprehensive assignments on the implementation of this receiver processing in Matlab will be given to the students. There will be a midterm which will be a take-home 24-hour exam. And then a final course project which will result in a presentation and report on the day of the final exam. This 2022 offering will also bring in the gitlab and slack collaborative tools for the class.

### **Textbook (not required)**

A Software-Defined GPS and Galileo Receiver: A Single-Frequency Approach; K. Borre, D. Akos, N. Bertelsen, P. Rinder, S. H. Jensen; 2007; ISBN-10: 978-0-8176-4390-4

### **Reference Material**

- 1) Course Notes
- 2) Understanding GPS/GNSS: Principles and Applications; E.D. Kaplan (Editor); 3<sup>rd</sup> ed; 2017; ISBN13: 978-1630810580
- 3) Global Positioning System: Signals, Measurements and Performance, P. Enge, P. Misra, 2<sup>nd</sup> ed; 2010, ISBN-13: 978-0970954428
- 4) ICDs for GPS - <http://www.gps.gov/technical/icwg/> (Also will refer to ICDs for other GNSS)
- 5) Global Positioning System: Theory & Applications; B. W. Parkinson (Editor), J. J. Spilker (Editor); Vol 1&2; 1996; ISBN13: 978-1563471063 & 978-1563471070 (new edition to be released shortly)
- 6) Fundamentals of Global Positioning System Receivers: A Software Approach; James Bao-Yen Tsui; 2000; ISBN13: 978-0471381549
- 7) Spread Spectrum Systems with Commercial Applications, R. C. Dixon, 3<sup>rd</sup> ed; 1994, ISBN13: 978-0471593423
- 8) Phase-Locked Loops : Design, Simulation, and Applications; R. Best; 6<sup>th</sup> ed; 2007; ISBN13: 978-0071493758

### **Course Schedule**

Week(s)	1	Course Introduction & GPS Software Receiver Overview (Assignment 1)
Week(s)	2	Front End Design/Data Collection
Week(s)	3 & 4	GNSS Signal Acquisition (Assignment 2 & 3)
Week(s)	5 & 6	GNSS Signal Tracking (Assignment 4 & 5)
Week(s)	7	Navigation Data Decoding (Assignment 6)
Week(s)	8	Position Solution (Assignment 7)
Week(s)	9	Differential Position Solution (Assignment 8)
Week(s)	10	Midterm & Project Proposal
Week(s)	11-15	Project Work

Final Exam/Presentation                      TBD (based on final exam schedule)

### **Course /Grades/Evaluation**

- 50% - Assignments
- 20% - Midterm (typically take-home 24 hour exam)
- 30% - Final (Course Project Presentation/Report)

### **Notes**

- 1) Comprehensive assignments will be assigned approximately once per week at the beginning of the term, expected to be worked individually
- 2) Each assignment will be based on a 100 point scale
- 3) A midterm should be expected during the tenth week of the semester, typically format is an individual “take-home” 24 hour exam
- 4) A final project, based on the material from two thirds (approximate) of the course will replace a final exam. The project will require both a presentation and written report/code submission. It will be possible to work in groups of two, if preferred given sufficient scope for the project.

*Material is preliminary and subject to change*

# SYLLABUS STATEMENTS

## Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the [classroom behavior](#) policy, the [Student Code of Conduct](#), and the [Office of Institutional Equity and Compliance](#).

## Requirements for COVID-19

As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. CU Boulder currently requires COVID-19 vaccination and boosters for all faculty, staff and students. Students, faculty and staff must upload proof of vaccination and boosters or file for an exemption based on medical, ethical or moral grounds through the MyCUHealth portal.

The CU Boulder campus is currently mask-optional. However, if public health conditions change and masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the “Accommodation for Disabilities” statement on this syllabus.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the Public Health Office ([contacttracing@colorado.edu](mailto:contacttracing@colorado.edu)). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the Public Health Office ([contacttracing@colorado.edu](mailto:contacttracing@colorado.edu)).

## Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](#). Contact Disability Services at 303-492-8671 or [dsinfo@colorado.edu](mailto:dsinfo@colorado.edu) for further assistance. If you have a temporary medical condition, see [Temporary Medical Conditions](#) on the Disability Services website.

## Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on

instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

## Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the [Honor Code](#). Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution ([honor@colorado.edu](mailto:honor@colorado.edu)); 303-492-5550). Students found responsible for violating the [Honor Code](#) will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the [Honor Code website](#).

## Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, protected-class discrimination and harassment, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these policies, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email [cureport@colorado.edu](mailto:cureport@colorado.edu). Information about university policies, [reporting options](#), and support resources can be found on the [OIEC website](#). Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of any issues related to these policies regardless of when or where they occurred to ensure that individuals impacted receive information about their rights, support resources, and resolution options. To learn more about reporting and support options for a variety of concerns, visit [Don't Ignore It](#).

## Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance.

See the [campus policy regarding religious observances](#) for full details.