

# ECG 722 Mixed-Signal Circuit Design

UNIVERSITY OF NEVADA LAS VEGAS

Department of Electrical and Computer Engineering

Spring 2022

Time: TBA

Class Location: TBA

Office Hours: Appointment Only

WebCampus: <https://webcampus.unlv.edu>

*Note:* The instructor reserves the right to change the syllabus as it relates to how the course is administered.

## Course Description

Design of data converters using sigma-delta techniques. Operation and design of custom digital filters for decimating and interpolating in analog-to-digital interfaces.

## Required Text

“CMOS Mixed-Signal Circuit Design,” R. Jacob Baker, 2nd Edition, John Wiley & Sons, 2009, ISBN 9780470290262.

## Learning Outcomes

After completing ECG 722, students will be able to:

1. Design noise-shaping data converters given a set of requirements such as bandwidth, clock speed, and signal-to-noise ratio.
2. Design, simulate, and implement the digital interpolation and decimation filters used in noise-shaping data converters.
3. Design, simulate, and implement the analog filters used for anti-aliasing and reconstruction in a data conversion system.
4. Discuss the limitations of op-amps and comparators used in noise-shaping data converters.
5. Simulate noise-shaping data converting circuits and systems and the filtering used.
6. Design a high-speed noise-shaping converter using a cascaded modulator or the K-Delta-1-Sigma topology.

## Evaluation Methods

Assignments: 25%

Midterm Exam: 25%

Term Project: 25%

Final Exam: 25%

## Grading Scale

A	93-100
A-	90-92
B+	87-89
B	83-86
B-	80-82
C+	77-79
C	73-76
C-	70-72
D+	67-69
D	63-66
D-	60-62
F	<=59

## Course Agenda/Schedule

Module/Week #	Content	Work Assigned/Due
1	1.1 Sinusoidal Signals – 1.1.1 The Pendulum Analogy and 1.1.2 The Complex (z-) Plane 1.2 Comb Filters - 1.2.1 The Digital Comb Filter, 1.2.2 The Digital Differentiator, 1.2.3 An Intuitive Discussion of the z-Plane, 1.2.4 Comb Filters with Multiple Delay Elements, and 1.2.5 The Digital Integrator	Homework 1 due
2	2.1.part1 Sampling - 2.1.1 Impulse Sampling and 2.1.2 Decimation 2.1.part2 Sampling - 2.1.3 The Sample-and-Hold (S/H), and 2.1.4 The Track-and-Hold (T/H)	Homework 2 due
3	2.1.part3 Sampling - 2.1.5 Interpolation	Homework 3 due
4	2.1.part4 Sampling - 2.1.6 K-path Sampling 2.2.part1 Circuits - 2.2.1 Implementing the S/H	Homework 4 due
5	4.1 SPICE Models for DACs and ADCs - 4.1.1 The Ideal DAC, 4.1.2 The Ideal ADC, 4.1.3 Number Representation, 4.2 Sinc-Shaped Digital Filters, and 4.2.1 The Counter 4.2 Sinc-Shaped Digital Filters - 4.2.2 Lowpass Sinc Filters, 4.2.3 Bandpass and Highpass Sinc Filters, and 4.2.4 Interpolation using Sinc Filters	Homework 5 due Homework 6 due
6	4.2.5 Decimation using Sinc Filters 5.1 Quantization noise - 5.1.1 Viewing the Quantization Noise Spectrum Using Simulations and Quantization Noise Voltage Spectral Density	Homework 7 due Homework 8 due

<b>Module/Week #</b>	<b>Content</b>	<b>Work Assigned/Due</b>
	5.2 Signal-to-Noise Ratio (SNR) - 5.2.1 Clock Jitter and 5.2.2 A Tool: The Spectral Density	
<b>7</b>	5.3 Improving SNR using Averaging - 5.3.1 Using Averaging to Improve SNR, 5.3.2 Linearity Requirements, 5.3.3 Adding a Noise Dither, 5.3.4 Jitter, and 5.3.5 Anti-Aliasing Filter 5.4 Using Feedback to Improve SNR 6.1 Passive Noise-Shaping	Homework 9 due Homework 10 due
<b>8</b>	Review for the midterm exam 6.1 Passive Noise-Shaping - 6.1.1 Signal-to-Noise Ratio and 6.1.2 Decimating and Filtering the Modulator's Output Midterm exam	Homework 11 due
<b>9</b>	6.1 Passive Noise-Shaping - 6.1.3 Offset, Matching, and Linearity 6.2 Improving SNR and Linearity - 6.2.1 Second-Order Passive Noise-Shaping and 6.2.2 Passive Noise-Shaping Using Switched-Capacitors	Homework 12 due Homework 13 due
<b>10</b>	6.3 Improving SNR and Linearity - 6.2.3 Increasing SNR using K-Paths and 6.2.4 Improving Linearity Using an Active Circuit 7.1 First-Order Noise Shaping - 7.1.1 Modulation Noise in First-Order NS Modulators, 7.1.2 RMS Quantization Noise in a First-Order Modulator, and 7.1.3 Decimating and Filtering the Output of a NS Modulator	Homework 14 due Homework 15 due
<b>11</b>	7.1.4 Pattern Noise from DC Inputs (Limit Cycle Oscillations), 7.1.5 Integrator and Forward Modulator Gain, 7.1.6 Comparator Gain, Offset, Noise, and Hysteresis, and, 7.1.7 Op-Amp Gain (Integrator Leakage) Discuss course projects	Homework 16 due
<b>12</b>	7.1.8 Op-Amp Settling Time, 7.1.9 Op-Amp Offset, 7.1.10 Op-Amp Input-Referred Noise, and 7.1.11 Practical Implementation of the First-Order NS Modulator Discuss oscillator design for course projects	Homework 17 due
<b>13</b>	7.2 Second-Order Noise Shaping - 7.2.1 Second-Order Modulator Topology, 7.2.2 Integrator Gain, and 7.2.3 Selecting Modulator (Integrator) Gains 7.3 Noise-Shaping Topologies - 7.3.1 Higher-Order Modulators, 7.3.2 Filtering the Output of an Mth-Order NS Modulator, 7.3.3 Implementing Higher-Order, Single-Stage Modulators, 7.3.4 Multi-Bit Modulators, and 7.3.5 Error Feedback	
<b>14</b>	7.3.6 Cascaded Modulators 8.1 Continuous-Time Bandpass Noise-Shaping - 8.1.1 Passive-Component Bandpass Modulators,	Homework 18 due

Module/Week #	Content	Work Assigned/Due
	8.1.2 Active–Component Bandpass Modulators, and 8.1.3 Modulators for Conversion at Radio Frequencies 8.2 Switched–Capacitor Bandpass Noise–Shaping – 8.2.1 Switched–Capacitor Resonators, 8.2.2 Second–Order Modulators, 8.2.3 Fourth–Order Modulators, and 8.2.4 Digital I/Q Extraction to Baseband	
15	9.1 The Topology (of a high–speed data converter) – 9.1.1 Clock Signals, 9.1.2 Implementation, 9.1.3 Filtering, 9.1.4 Discussion, and 9.1.5 Understanding the Clock Signals Review for final exam	Term project report due
16	Final Exam	

# University Policies

## Public Health Directives

Face coverings are currently mandatory for all faculty and students in the classroom. Students must follow all active UNLV public health directives while enrolled in this class. UNLV public health directives are found at [Health Requirements for Returning to Campus](https://www.unlv.edu/coronavirus/health-requirements), <https://www.unlv.edu/coronavirus/health-requirements>. Students who do not comply with these directives may be asked to leave the classroom. Refusal to follow the guidelines may result in further disciplinary action according to the [UNLV Student Conduct Code](https://www.unlv.edu/sites/default/files/page_files/27/StudentConduct-Code.pdf), [https://www.unlv.edu/sites/default/files/page\\_files/27/StudentConduct-Code.pdf](https://www.unlv.edu/sites/default/files/page_files/27/StudentConduct-Code.pdf), including being administratively withdrawn from the course.

## Academic Misconduct

Academic integrity is a legitimate concern for every member of the University community. We all share in upholding the fundamental values of honesty, trust, respect, fairness, responsibility, and professionalism. By choosing to join the UNLV community, students accept the expectations of the Student Academic Misconduct Policy, and are encouraged to always take the ethical path whenever faced with choices. Students enrolling at UNLV assume the obligation to conduct themselves in a manner compatible with UNLV’s educational mission. An example of academic misconduct is plagiarism. Plagiarism is using the words or ideas of another person, from the Internet or any other source without proper citation of the source(s). See the [Student Conduct Code](https://www.unlv.edu/studentconduct/student-conduct), <https://www.unlv.edu/studentconduct/student-conduct>.

## Auditing a Course

Auditing a course allows a student to continue attending the lectures and/or laboratories and discussion sessions associated with the course, but the student will not earn a grade for any component of the course. Students who audit a course receive the same educational experience

as students taking the course for a grade, but will be excused from exams, assessments, and other evaluative measures that serve the primary purpose of assigning a grade.

## **Classroom Conduct**

Students have a responsibility to conduct themselves in class and in the libraries in ways that do not interfere with the rights of other students to learn, or of instructors to teach. Use of devices such as cellular phones and pagers, or other potentially disruptive activities are only permitted with the prior explicit consent of the instructor. Students are specifically prohibited to record classes without instructor authorization, including online/remote classes (either audio only, or video and audio). The instructor may rescind permission at any time during the class. If a student does not comply with established requirements or obstructs the functioning of the class, the instructor may initiate an administrative withdrawal of the student from the course.

Since the COVID-19 pandemic forced some instruction to be delivered remotely starting in Spring 2020, numerous students have asked instructors to record their synchronous classes, so that they can access them at their convenience. Instructors who agree to record their classes (audio only, or video and audio) should inform students in advance. Recorded lectures may not be broadly released to anyone, but made available exclusively to those students enrolled in the class during the particular academic term. Recorded lectures must be stored securely, and are subject to the Nevada System of Higher Education's Records Retention Policy, meaning that the recordings can only be deleted 120 days after the end of class (i.e., after grades are posted). Once this requirement is met, the recordings should be deleted. Class recordings are protected from disclosure, as they are deemed part of an educational record under the Family Educational Rights and Privacy Act (FERPA).

## **Copyright**

The University requires all members of the University Community to familiarize themselves with, and to follow copyright and fair use requirements. You are individually and solely responsible for violations of copyright and fair use laws. The University will neither protect nor defend you, nor assume any responsibility for student or employee violations of fair use laws. Violations of copyright laws could subject you to federal and state civil penalties and criminal liability, as well as disciplinary action under University policies. Additional [copyright policy information](https://www.unlv.edu/provost/copyright) is available at <https://www.unlv.edu/provost/copyright>.

## **Disability Resource Center (DRC)**

The [UNLV Disability Resource Center](https://www.unlv.edu/drc) (Student Services Complex, SSC-A, Room 143, <https://www.unlv.edu/drc>, telephone 702-895-0866) provides resources for students with disabilities. Students who believe that they may need academic accommodations due to a permanent disability, temporary or permanent medical need, or academic support due to pregnancy are encouraged to contact the DRC as early as possible in the academic term. A Disabilities Specialist will discuss what options may be available to you. Students who are already registered with the DRC should request their accommodations online each semester, and make an appointment to discuss their accommodations with their instructors.

## **Final Examinations**

The University requires that final exams given at the end of a course occur on the date and at the time specified in the Final Exam schedule. The Final Exam schedule is typically available at the start of the semester, and the classroom locations are available approximately one month before the end of the semester. See the [Final Exam Schedule](https://www.unlv.edu/registrar/calendars), <https://www.unlv.edu/registrar/calendars>.

## **Identity Verification in Online Courses**

All UNLV students must use their Campus-issued ACE ID and password to log in to WebCampus-Canvas.

UNLV students enrolled in online or hybrid courses are expected to read and adhere to the [Student Academic Misconduct Policy](https://www.unlv.edu/studentconduct/misconduct/policy), <https://www.unlv.edu/studentconduct/misconduct/policy>, which states that “acting or attempting to act as a substitute for another, or using or attempting to use a substitute, in any academic evaluation or assignment” is a form of academic misconduct. Intentionally sharing ACE login credentials with another person may be considered an attempt to use a substitute, and could result in investigation and sanctions, as outlined in the Student Academic Misconduct Policy.

UNLV students enrolled in online courses are also expected to read and adhere to the [Acceptable Use of Computing and Information Technology Resources Policy](https://www.it.unlv.edu/policies/acceptable-use-computing-and-information-technology-resources-policy), <https://www.it.unlv.edu/policies/acceptable-use-computing-and-information-technology-resources-policy>, which prohibits sharing university accounts with other persons without authorization.

To the greatest extent possible, all graded assignments and assessments in UNLV online courses should be hosted in WebCampus-Canvas or another UNLV-managed platform that requires ACE login credentials for access.

## **Incomplete Grades**

The grade of “I” (Incomplete) may be granted when a student has satisfactorily completed three-fourths of course work for that semester/session, but cannot complete the last part of the course for reason(s) beyond the student’s control and acceptable to the instructor, and the instructor believes that the student can finish the course without repeating it. For undergraduate courses, the incomplete work must be made up before the end of the following regular semester. Graduate students receiving “I” grades in 500-, 600-, or 700-level courses have up to one calendar year to complete the work, at the discretion of the instructor. If course requirements are not completed within the period indicated, a grade of “F” will be recorded, and the student’s GPA will be adjusted accordingly. Students who are fulfilling an Incomplete grade do not register for the course, but make individual arrangements with the instructor who assigned the “I” grade.

## **Library Resources**

Librarians are available to consult with students on research needs, including developing research topics, finding information, and evaluating sources. To make an appointment with a subject expert for this class, please visit the [Libraries' Research Consultation](https://guides.library.unlv.edu/appointments/librarian) website, <https://guides.library.unlv.edu/appointments/librarian>. You can also [ask the library staff](https://ask.library.unlv.edu/) questions via chat and text message at <https://ask.library.unlv.edu/>.

## **Missed Classwork**

Any student missing class, quizzes, examinations, or any other class or laboratory work because of observance of religious holidays will be given an opportunity during that semester to make up the missed work. The make-up opportunity will apply to the religious holiday absence only. It is the responsibility of the student to notify the instructor within the first 14 calendar days of the course for Fall and Spring courses (except for modular courses), or within the first 7 calendar days of the course for Summer and modular courses, of their intention to participate in religious holidays which do not fall on state holidays or periods of class recess. For additional information, please visit the Missed Classwork policy, under Registration Policies, on the [Academic Policies](https://catalog.unlv.edu/content.php?catoid=32&navoid=8271&hl=) webpage, <https://catalog.unlv.edu/content.php?catoid=32&navoid=8271&hl=>.

In accordance with the policy approved by the Faculty Senate regarding missed class time and assignments, students who represent UNLV in any official extracurricular activity will also have the opportunity to make up assignments, provided that the student submits official written notification to the instructor no less than one week prior to the missed class(es).

The spirit and intent of the policy for missed classwork is to offer fair and equitable assessment opportunities to all students, including those representing the University in extracurricular activities. Instructors should consider, for example, that in courses which offer a “Drop one” option for the lowest assignment, quiz, or exam, assigning the student a grade of zero for an excused absence for extracurricular activity is both contrary to the intent of the Faculty Senate’s policy, and an infringement on the student’s right to complete all work for the course.

This policy will not apply in the event that completing the assignment or administering the examination at an alternate time would impose an undue hardship on the instructor or the University that could be reasonably avoided. There should be a good faith effort by both the instructor and the student to agree to a reasonable resolution. When disagreements regarding this policy arise, decisions can be appealed to the Department Chair/School Director, College/School Dean, and/or the Faculty Senate Academic Standards Committee.

For purposes of definition, extracurricular activities may include, but are not limited to academic recruitment activities, competitive intercollegiate athletics, fine arts activities, liberal arts competitions, science and engineering competitions, and any other event or activity sanctioned by a College/School Dean, and/or by the Executive Vice President and Provost.

## **Rebelmail**

Rebelmail is UNLV’s official email system for students and by University policy, instructors and staff should only send emails to students’ Rebelmail accounts. Rebelmail is one of the primary

ways in which students receive official University communications, information about deadlines, major Campus events, and announcements. All UNLV students receive a Rebelmail account after they have been admitted to the University. Sending emails within WebCampus-Canvas is also acceptable.

## **Tutoring and Coaching**

The Academic Success Center (ASC), at the Claude I. Howard Building, provides tutoring, academic success coaching, and other academic assistance for all UNLV undergraduate students. For information regarding tutoring subjects, tutoring times, and other ASC programs and services, please visit the [ASC website](https://www.unlv.edu/asc), <https://www.unlv.edu/asc>, or call 702-895-3177. The ASC is located across from the Student Services Complex (SSC). Academic success coaching is located on the second floor of SSC A, Room 254. Drop-in tutoring is located on the second floor of the Lied Library, and on the second floor of the College of Engineering building (TBE A 207).

## **UNLV Writing Center**

One-on-one or small group assistance with writing is available free of charge to UNLV students at the [Writing Center](https://writingcenter.unlv.edu/), <https://writingcenter.unlv.edu/>, located in the Central Desert Complex, Building 3, Room 301 (CDC 3–301). Walk-in consultations are sometimes available, but students with appointments receive priority assistance. Students may make appointments in person or by calling the Center, telephone 702-895-3908. Students are requested to bring to their appointments their Rebel ID Card, a copy of the instructions for their assignment, and two copies of any writing they have completed on their assignment.

Optional statements for inclusion in syllabi.

## **Diversity Statement**

As an institution of higher learning, UNLV represents a rich diversity of human beings among its faculty, staff, and students, and is committed to aspiring to maintain a Campus environment that values that diversity. Accordingly, the University supports understanding and appreciation of all members of its community, regardless of race, sex, age, color, national origin, ethnicity, creed, religion, disability, sexual orientation, gender, gender identity, marital status, pregnancy, genetic information, veteran status, or political affiliation. Please see [University Statements and Compliance](https://www.unlv.edu/about/statements-compliance), <https://www.unlv.edu/about/statements-compliance>.

A successful learning experience requires mutual respect and trust between the students and the instructor. Accordingly, the instructor asks that students be willing to listen to one another's points of view, acknowledging that there may be disagreements, keep discussion and comments on topic, and use first person, positive language when expressing their perspectives.

## **UNLV Land Acknowledgement**



UNLV is situated on the traditional homelands of Indigenous groups, including the Nuwu or Nuwuvi, Southern Paiute People, descendants of the Tudu, or Desert People. We honor and offer gratitude for those who have stewarded the land; for the land itself; and for the opportunity to cultivate a thriving, diverse, inclusive, and just scholarly community here today that works for a better tomorrow for all.