



The University of New Mexico

Electrical and Computer Engineering Department  
Nonlinear & Adaptive Control, EECE 514

## **COURSE SYLLABUS**

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### ***Instructor Information...***

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### ***Course Description***

In this course, you will learn how to analyze and design nonlinear systems. The first part will concentrate on the analysis of continuous-time nonlinear systems and different stability concepts. These will include basic and advance Lyapunov stability concepts (passivity, input-state stability). The second part will deal with various control design for uncertain linear and nonlinear systems using the concepts of the first part. Such designs include adaptive and robust control techniques (feedback linearization, backstepping, etc). Applications of the theoretical results presented will be investigated in a number of examples and problems.

This course will require a basic understanding of matrices, differential equations, and a familiarity with state-space concepts. I expect you to spend about 18 hours per week on the material covered in the course.

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### ***Prerequisites***

Since this is an online course, there are some minimum hardware and software requirements to complete the course. For recommended operating system requirements and web browser compatibility, see <http://webct.unm.edu/home/setup/system.html>.

For all browsers, JavaScript and cookies must be enabled. To use Chat and Whiteboard, Java must also be enabled. Please see <http://webct.unm.edu/home/setup/browser.html> for details on internet browser setups.

Students will need access to Microsoft Word and PowerPoint for this course. In addition, students will need to obtain [WinZip](#) and [Adobe Acrobat Reader](#), which can be downloaded for free from the Internet.

Homework assignments will be submitted electronically via WebCT. Students will be expected to have access to a scanner for digitizing any handwritten assignments.

**This course has the following academic prerequisites:**

- Prerequisite 1: ECE 500 (Linear Systems) or consent of the instructor
- Prerequisite 2: EECE 314 (Signals & Communications), and Math 321 (Linear Algebra) or Math 464 (Applied Matrix Theory).

In addition to specific academic courses, students are expected to have familiarity with the following computer programs: **Matlab**. Please see “Using Matlab at UNM” under the resources icon in your course, to familiarize yourself with how to access UNM Matlab licenses on-campus and off-campus.

You will also need access to a fax or a scanner to submit handwritten homework assignments.

This course is available to full-time students and non-degree students attending part-time.

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## **Getting Started**

In order to get oriented to this WebCT course, you should complete the following assignments in the order listed below:

1. WebCT Orientation – Start Here Button on the ECE 500 Homepage
2. Install the Matlab Software sent to you (if you do not have your own!)

If you are having technical problems with WebCT, you can contact free technical support through one of the following ways:

- Phone: (505) 277-7490
- Email: [webct@unm.edu](mailto:webct@unm.edu)
- Web: <http://webct.unm.edu>

Any course content related questions should be directed to your assigned instructor. Please refer to contact information.

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## ***Texts & Readings***

The textbook for the course is:

H.K. Khalil, *Nonlinear Systems*, Prentice-Hall, Third Ed., 2002.

Other recommended textbooks and resources are listed in Module 1 of the course.

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## ***Policy***

**ALL ANNOUNCEMENTS/CHANGES/DUE DATES WILL BE POSTED ON WEBCT: IT IS THE STUDENT'S RESPONSIBILITY TO CHECK THEIR WEBCT ACCOUNT AND CALENDAR FOR COMMUNICATIONS AND CHANGES TO THE COURSE SEVERAL TIMES A WEEK. A GRADE OF ZERO WILL BE GIVEN FOR ASSIGNMENTS NOT COMPLETED BY THEIR DUE DATE. NO LATE ASSIGNMENTS OR QUIZZES WILL BE ACCEPTED.**

**Academic Integrity:** Each student is expected to maintain the highest standards of honesty and integrity in academic and professional manners. The University reserves the right to take disciplinary action, up to and including dismissal, against any student who is found guilty of academic dishonesty or otherwise fails to meet these standards.

**Access to Education:** Qualified students with disabilities needing appropriate academic adjustments should contact the instructor as soon as possible to ensure your needs are met in a timely manner. For information on assistive technology available for student use and additional information on services available through Student Accessibility Services, see <http://www.unm.edu/~sss/>.

**Audit:** A student may register for a course as an auditor, providing permission of the instructor is obtained. A student has the first four weeks of the semester to change a course to audit status. No changes in audit status will be processed after the fourth week of class. Students are charged the normal tuition rate for auditing a course.

**Collaboration:** Collaborative work, such as studying or discussing course assignments and materials, with other class members is highly encouraged. Students are encouraged to collaborate with each other using the WebCT email discussion area tools. The discussion area called 'Student Café' is one place to share ideas with others in the class.

**Copyright:** All materials in this course fall under copyright laws and should not be downloaded, distributed, or used by students for any purposes outside of this course.

**Exams:** It will be the student's responsibility to arrange for proctoring for closed-book exams. Common locations include local libraries and Extended University branch centers. Please contact New Media and Extended Learning at (505) 277-5765 for additional suggestions or assistance.

**Office Hours & Contacting the Instructor:** Office hours will be upon request. Generally, I am in my office between 10:00 AM and 3:00 PM daily. You may call me at (505)277-0298, or send me an email through WebCT email during normal Monday-Friday, 8-5 hours, and you can expect to receive an initial reply within 24 hours. Where appropriate, students are encouraged to post their questions to the discussion areas so that other students can benefit, and/or another student may be able to answer your question.

**Privacy and WebCT Tracking Notice:** WebCT or the course Web site automatically records all students' activities, including, your first and last access to the course, the pages you have accessed, the number of conferencing messages you have read and sent, chat rooms discussions, and posted discussion topics. This data is accessed by the instructor to evaluate class participation and to identify students having difficulty using WebCT features.

**Incompletes, Withdrawals, and Drops:** I give out incompletes only under extreme circumstances. If you are running into problems with the course, please contact me as early as possible so you do not fall behind.

This course falls under all UNM policies for last day to drop courses, etc. Please see <http://www.unm.edu/studentinfo.html> or the [UNM Course Catalog](#) for information on UNM services and policies. Please see the [UNM academic calendar](#) for course dates, the last day to drop courses without penalty, and for Financial Disenrollment dates.

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## **Assignments and Grading Criteria**

This is an intensive, graduate-level course with regular and firm deadlines. As such, you should expect to spend at least 15 hours working on the course each week. This includes readings, viewing course content, completing homework assignments, posting to the discussion area, etc.

### **Weekly Assignments**

There will be three types of weekly assignments in this course, which are described below.

1. **Weekly Discussion Topics:** are, in essence the equivalent of "class participation" in this online course. The instructor will begin facilitation of these class discussions. Each discussion topic will last for approximately one-week. Please log into the class and participate in the discussion at least twice during the one-week window. You can find out the start and end times for each discussion topic in the course calendar.

You are expected to participate in all of the discussion topics presented during the semester. You are encouraged to share your ideas, ask questions, and comment/respond appropriately to other students' comments. The instructor will evaluate

your discussion postings in terms of both quality and quantity as part of the course grade. **The weekly discussion will comprise 20% of the course grade.**

2. **Weekly Assignments:** Assignments will be posted approximately weekly. The total number of assignments will be approximately 10. These will not be graded, but you are encouraged to check the solutions provided to you.
  1. Total number assignments- 10
  2. Open book
  3. Collaboration acceptable and encouraged
  4. Solutions will be posted in WebCT each Monday for the assignment due the previous week
3. **Quizzes & Midterm:** There will be bi-weekly quizzes (5 total) in a multiple-choice format. You may take each quiz only once. The quizzes closely follow the information presented in the WebCT lectures and the textbook.
  - Total number of quizzes – 5 worth: 30% of grade
  - Midterm: worth 20% of grade
  - Each quiz can be taken only ONCE, before the deadline
  - Open book and open notes
  - Collaboration unacceptable
  - Timed – Students will have one hour to complete the quiz. Although the format of the quizzes is multiple-choice, if students FAX in or scan and e-mail their solutions within 24 hours of uploading the quiz, partial credit will be assigned as warranted.

**REMINDER about Late Submissions:** All final dates for taking assignments and quizzes are posted on the course calendar and on the quiz page. You will receive zero points for any quiz or assignment not completed by the deadline.

**Mid-term Exams:** There will be 1 midterm exam as described above, worth 20% of the grade. Unofficial midterm grades will be posted so that the student understands her/his standing in the course.

4. **Final Exam:** You will have an open-book final exam project in this course. This is similar to an extensive take-home exam. It will be open book, but NO collaboration is allowed. Please see the calendar for details on the date and form of this exam.
    - Worth : 30% of grade
    - Open Book, open notes, open anything
-

<i>Final Grade</i>	<i>Percent</i>
Discussion Postings	20
Midterm	20
Biweekly Exams	30
Final Exam	30

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### **Course Evaluation**

You will be asked to complete a mid-term and final course evaluation survey online for this course. These surveys are completely anonymous and provide useful information to improve this course for next semester's students. These surveys will be listed on the calendar and will appear in the quizzes section of the course. If you have any questions or concerns about the survey, please ask the instructor.

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### **Course Outline**

#### **Module 1: Introduction to WebCT**

**Objective:** Become familiar with how to operate in the online WebCT environment & course policies. Go through the "Start Here" button on the course web site.

#### **Module 2: Introduction**

**Objective:** To introduce nonlinear systems and differential equations.

**Topics:** Autonomy, equilibrium points. Mathematical preliminaries and nonlinear differential equations.

#### **Module 3: Mathematical Background on Differential Equations**

**Objective:** To present some linear algebra and real analysis concepts to help in studying differential equations.

**Topics:** Vector spaces, norms, contraction mappings, existence and uniqueness of solutions. See Chapter 1, 2, 3.

#### **QUIZ 1: Covers modules 2-3**

#### **Module 4: Lyapunov Stability**

Objective: To introduce Lyapunov stability concepts.

Topics: Fundamentals of Lyapunov stability. First and second methods of Lyapunov. Applications to linear and nonlinear systems. See Chapter 4.

**QUIZ 2: Covers modules 2-4**

#### **Module 5: Advanced Stability Concepts**

Objective: To introduce advanced stability concepts beyond Lyapunov stability

Topics: Input-Output Stability. L-Stability. Feedback systems. Small-Gain theorem.

#### **Module 6: Further Stability Concepts**

Objective: To further expand stability concepts and applications

Topics: Advanced stability concepts, passivity, absolute stability, input-output stability concepts. See Chapters 6, 7 and notes.

**QUIZ 3: Covers modules 2-6**

#### **Module 7: Differential Geometric & Feedback Linearization**

Objective: To introduce differential geometric concepts and design techniques.

Topics: Basic differential geometry and feedback-linearization methods. See notes, Chapter 12, 13.

**QUIZ 4: Covers modules 2-7**

#### **Module 8: Basic Adaptive Control Methods**

Objective: To present model reference adaptive control as a Lyapunov stability application.

Topics: Introduction to Adaptive control. Model-Reference. Identification, convergence and stability. Adaptive control of linear systems using state-feedback, and output-feedback. See Chapter 13 and notes.

#### **Module 9: Adaptive Control of Nonlinear Systems**

Objective: Applications of Lyapunov stability to nonlinear systems.

Topics: Adaptive control of nonlinear systems. Robotics and other examples. See notes.

#### **Module 10: Advanced topics and applications**

Objective: To present recent research problems in nonlinear systems.

**QUIZ 5: Covers modules 2-7**

**END OF COURSE**