

REQUEST FOR ADDITION, EXPIRATION,  
OR REVISION OF A COURSE

DEPARTMENT Electrical and Computer Engineering

EFFECTIVE SESSION Spring 2006

INSTRUCTIONS: Please check the items below which describe the purpose of this request.

- |   |  |
|---|--|
| <input checked="" type="checkbox"/> 1. New course with supporting documents | <input type="checkbox"/> 7. Change in course attributes              |
| <input type="checkbox"/> 2. Add existing course                             | <input type="checkbox"/> 8. Change in instructional hours            |
| <input type="checkbox"/> 3. Expiration of a course                          | <input type="checkbox"/> 9. Change in course description             |
| <input type="checkbox"/> 4. Change in course number                         | <input type="checkbox"/> 10. Change in course requisites             |
| <input type="checkbox"/> 5. Change in course title                          | <input type="checkbox"/> 11. Change in semesters offered             |
| <input type="checkbox"/> 6. Change in course credit/type                    | <input type="checkbox"/> 12. Transfer from one department to another |

**PROPOSED:** Subject Abbreviation \_\_\_\_\_ Course Number \_\_\_\_\_ Long Title Linear Multivariable Control Short Title Linear Multivar Contrl  
Abbreviated title will be entered by the Office of the Registrar if omitted. (22 CHARACTERS ONLY)

**EXISTING:** Subject Abbreviation ECE Course Number 684

**TERMS OFFERED**  
Check All That Apply:  
Summer  Spring  Fall

**CAMPUS(ES) INVOLVED**  
Calumet  Ft. Wayne   
Indianapolis  N. Central   
W.Lafayette  Cont Ed   
Tech Statewide

**CREDIT TYPE**

1. Fixed Credit: Cr. Hrs. 3

2. Variable Credit Range: Minimum Cr. Hrs \_\_\_\_\_ (Check One) To  Or  Maximum Cr. Hrs \_\_\_\_\_

3. Equivalent Credit: Yes  No

4. Thesis Credit: Yes  No

**COURSE ATTRIBUTES: Check all That Apply**

1. Pass/Not Pass Only

2. Satisfactory/Unsatisfactory Only

3. Repeatable   
Maximum repeatable credit: \_\_\_\_\_

4. Credit by Examination

5. Designator Required

6. Special Fees

7. Registration Approval Type  
Department  Instructor

8. Variable Title

9. Remedial

10. Honors

11. Full Time Privilege

12. Off Campus Experience

Instructional Type	Minutes Per Mtg	Meetings Per Week	Weeks Offered	% of Credit Allocated	Delivery Method (Asyn. Or Syn)	Delivery Medium(Audio,Internet, Live,Text-Based, Video)
Lecture	75	2	16	100		
Recitation						
Presentation						
Laboratory						
Lab Prep						
Studio						
Distance						
Clinic						
Experiential						
Research						
Ind. Study						
Pract/Observ						

**Cross-Listed Courses**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**COURSE DESCRIPTION (INCLUDE REQUISITES):**

A state space investigation of multi-input, multi-output control design problems from the geometric perspective. The course will detail the theory and design algorithms needed for a solution to the state feedback eigenvalue assignment problem, the disturbance decoupling problem with and without internal stability, the output stabilization problem, and the tracking (or regulator) problem with internal stability. Offered in alternate years.

Calumet Undergrad Curriculum Committee	Date	Calumet Department Head	Date	Calumet School Dean	Date
Fort Wayne Department Head	Date	Fort Wayne School Dean	Date	Fort Wayne Chancellor	Date
<i>[Signature]</i>	<u>9/8/05</u>	<i>[Signature]</i>	<u>11/9/05</u>		
Indianapolis Department Head	Date	Indianapolis School Dean	Date	Undergrad Curriculum Committee	Date
North Central Department Head	Date	North Central Chancellor	Date	Date Approved by Graduate Council	
<i>[Signature]</i>	<u>8/24/07</u>				
West Lafayette Department Head	Date	West Lafayette College/School Dean	Date	Graduate Council Secretary	Date
Graduate Council Area Committee Chair	Date	Graduate Dean	Date	West Lafayette Registrar	Date

New Course Request

Indiana University

IUPUI

Campus

Check Appropriate Boxes: Undergraduate credit  Graduate credit  Professional credit

1. School/Division Engineering & Technology 2. Academic Subject Code ECE

3. Course Number 684 (must be cleared with University Enrollment Services) 4. Instructor S. Koskie

5. Course Title Linear Multivariable Control

Recommended Abbreviation (Optional) \_\_\_\_\_  
(Limited to 32 Characters including spaces)

6. First time this course is to be offered (Semester/Year): SPRING 2008

7. Credit Hours: Fixed at 3 or Variable from \_\_\_\_\_ to \_\_\_\_\_

8. Is this course to be graded S-F (only)? Yes \_\_\_\_\_ No X

9. Is variable title approval being requested? Yes \_\_\_\_\_ No X

10. Course description (not to exceed 50 words) for Bulletin publication: P: ECE 602 or equivalent.

A state space investigation of multi-input, multi-output control design problems from the geometric perspective. The course will detail the theory and design algorithms needed for a solution to the state feedback eigenvalue assignment problem, the disturbance decoupling problem with and without internal stability, the output stabilization problem, and the tracking (or regulator) problem with internal stability. Offered in alternate years.

11. Lecture Contact Hours: Fixed at 3 or Variable from \_\_\_\_\_ to \_\_\_\_\_

12. Non-Lecture Contact Hours: Fixed at 0 or Variable from \_\_\_\_\_ to \_\_\_\_\_

13. Estimated enrollment: 10 of which 100 percent are expected to be graduate students.

14. Frequency of scheduling: every other year Will this course be required for majors? NO

15. Justification for new course: ECE faculty member is interested in this area.

16. Are the necessary reading materials currently available in the appropriate library? YES

17. Please append a complete outline of the proposed course, and indicate instructor (if known), textbooks, and other materials.

18. If this course overlaps with existing courses, please explain with which courses it overlaps and whether this overlap is necessary, desirable, or unimportant.

19. A copy of every new course proposal must be submitted to departments, schools, or divisions in which there may be overlap of the new course with existing courses or areas of strong concern, with instructions that they send comments directly to the originating Curriculum Committee. Please append a list of departments, schools, or divisions thus consulted.

Submitted by:

Approved by:

[Signature]  
Department Chairman / Division Director

Date 9/8/05

[Signature]  
Dean

Date 11/9/05

[Signature]  
Dean of Graduate School (when required)

Date 11/9/05

\_\_\_\_\_  
Chancellor / Vice-President

Date \_\_\_\_\_

\_\_\_\_\_  
University Enrollment Services

Date \_\_\_\_\_

After School / Division approval, forward the last copy (without attachments) to University Enrollment Services for initial processing, and the remaining four copies and attachments to the Campus Chancellor or Vice-President.



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### West Lafayette Schedules

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[Evening Exam Schedule](#)

[Final Exam Schedule](#)

## Course List >> West Lafayette >> Traditional Programs >> ECE - Electrical & Computer Engineering

**Search Summary:** 1 retired course, 1 current course, and 0 courses to be activated in the future.

Effective dates of retired items appear in *italicized red*; effective dates of current items appear in black; effective dates of future items appear in **bolded green**.

[Show Retired](#) | [Hide Current](#) | [Hide Future](#)

## ECE 684 - Linear Multivariable Control

**Information** 05/19/2003 - Forward

**Effective:**

**Credits:** 3.00

**Typical Instructional Format:** Lecture that meets 3 times per week for 50 minutes per meeting for 16 weeks.

**Usually Offered:** Spring

**Short Title:** Linear Multivar Contrl

**Description:** A state space investigation of multi-input, multi-output control design problems from the geometric perspective. The course will detail the theory and design algorithms needed for a solution to the state feedback eigenvalue assignment problem, the disturbance decoupling problem with and without internal stability, the output stabilization problem, and the tracking (or regulator) problem with internal stability. Offered in alternate years.

**School:** School Of Electrical And Computer Engineering

**Department:** Electrical & Computer Engineering

**Credit By Exam:** Credit by examination is not available for this course.

**Pre/Corequisites:** Prerequisite: [ECE 602](#). Authorized equivalent courses or consent of instructor may be used in satisfying course pre- and co-requisites.

## 15 Course Justification

The Graduate program in Electrical and Computer Engineering (ECE) has grown over the past few years. There are now more faculty with expertise in control, and more students who wish to do a Master's or Ph.D. thesis in the area of control than there have been in the past. ECE 684 is a crucial course in the area, and as such many students who wish to pursue a Master's degree and all students who wish to pursue a Ph.D. in control will need this course. ECE 684 has not yet been offered at IUPUI, but has been offered at Purdue. We need to teach the course at IUPUI as part of a viable ECE graduate program. Students should not have to commute to W. Lafayette to take the courses they need in order to complete their degrees.

# ECE 684 Linear Multivariable Control

## Catalogue Description

3 credits. A state space investigation of multi-input multi-output control design problems from the geometric perspective. The course will detail the theory and design algorithms needed for a solution to the state feedback eigenvalue assignment problem, the disturbance decoupling problem with and without internal stability, the output stabilization problem, and the tracking (or regulator) problem with internal stability.

Prerequisites: ECE602 (Lumped System Theory) or equivalent

## Course Information

- Lecture: tbd
- Instructor: Sarah Koskie
- Office Hours: tbd, or by appointment, in SL 164F
- Email: skoskie@iupui.edu
- Objectives: Students will become familiar with the basic concepts and methods of linear multivariable control and be able to apply them appropriately to the analysis and design of control systems. They should become comfortable using the literature to identify and implement refinements to these procedures as needed.
- Text: W. M. Wonham, *Linear Multivariate Control* (third edition), Springer-Verlag, 1985. (Any edition will suffice.) Some lecture notes will also be provided.
- Prerequisite: ECE 602 or equivalent. Students should be comfortable with matrix and vector algebra.
- Grading: Homework 100%

## Homework Assignments

Homework assignments will require students to solve both theoretical and practical problems. Some problems will include calculations that may be most conveniently performed on a computer. The students may use any software tools, but must turn in sufficient documentation to show how they solved the problem. Such documentation should include scripts written, block diagrams of simulation models, and plots of inputs, outputs, and states as appropriate. Students will be graded based on the accuracy of their calculations and the correctness of their solution methods. Homework assignments will be announced in class and posted on the web. Each homework assignment is due in class on the assigned date, which will be announced in class and posted to the course website. Homework may be submitted as pdf files by email before class. Please do not send obscure formats, zipped files, or extremely long files.

- Late homework will NOT be accepted.
- Work submitted should be the student's own.
- All necessary steps towards obtaining the solution, as well as any Matlab code, must be

included in the write up for full credit.

There will be approximately ten homework assignments during the course of the semester. Each student's lowest two scores will be dropped. Students should keep returned homework as results of some problems may be used in later homework assignments.

Students are allowed, even encouraged, to work on the homework in small groups, but each student must hand in an individual set of answers, which must be their own work. Students may discuss the problems but should not work jointly on them. Discussions should be noted, e.g. "John and I compared approaches to this problem because we found our results surprising; but after considering the alternatives decided that we both had the right approach." or "I kept getting a negative number for an answer and Jane suggested I check whether I forgot to whiten the data, which I had. I fixed this and got the answer indicated." or "John and Jane and I couldn't see how to approach this and Jean suggested . . . which yielded a successful approach." Each student must write their own Matlab code where needed.

Cheating will result in a grade of F in the course. Don't do it. It's better to just get a low grade on one assignment if you find yourself unable to complete it in the allotted time. That still leaves you a chance of passing the course.

Students are referred to the code of student conduct at <http://www.iupui.edu/code/#page>.

## **Grading Scale**

As stated above, the grade will be based entirely on the homework, which the student is expected to submit on or before the stated due date. For this reason, the student is expected to complete all of the homework, asking questions of the instructor during office hours, if necessary.

A	90-100
B	80-89
C	70-79
D	60-69
F	<60

## **Detailed Course Outline/ Syllabus**

Controllability and spectral assignability: (4 lectures) Conditions under which closed loop system eigenvalues can be reassigned are discussed. Then, once the theory has been understood, the process of designing state feedback controls to achieve eigenvalue reassignment will be discussed and Matlab will be used to implement and test such controllers.

Disturbance decoupling problem (DDP): (5 lectures)

A practical controller design should ideally prevent deterministic disturbance inputs from having any influence on the controlled output of the system. Theory and application of disturbance-decoupling controllers will be discussed as will the conditions under which they can be designed. Matlab will be used to implement and test control designs.

Output stabilization problem (OSP): (5 lectures) One common control objective is to use control inputs to bring output error to zero within an appropriately short time. Theory and design of state feedback to stabilize specified output variables will be discussed. Controllers will be implemented and tested in Matlab.

Disturbance Decoupling with Internal Stability: (6 lectures) In these lectures we revisit the disturbance decoupling problem with the objective of requiring also that the system remain internally stable. Theory will be applied and tested by designing, implementing and testing controllers in Matlab.

Tracking and regulation: (5 lectures)

An alternative control objective to simply driving controlled output to a constant value is the goal of achieving zero tracking error in following a specified trajectory. Tracking controllers will be tested in simulation using Matlab.

Balanced Model Reduction: (3 lectures) The use of the matrix Lyapunov equation in model reduction strategies will be investigated. Model reduction and its effect on controller design and performance will be investigated and results tested in Matlab.

LQ Control: (3 lectures) Linear Quadratic (LQ) control constitutes one of the simplest optimal control strategies, and as such is an important topic in any control course. We will discuss existence and uniqueness of solutions, the role of the matrix Riccati equation, and controller limitations. Controllers will be implemented and tested in Matlab.

## **Bibliography**

The following references are relevant to various portions of the material to be presented in this course and will be consulted as appropriate.

- *Essentials of Robust Control* by K. Zhou and J. C. Doyle, Prentice-Hall, 1998.
- *Linear Controller Design: Limits of Performance* by Stephen P. Boyd and Craig H. Barrett, Prentice-Hall, 1991.
- *Linear Systems* by Thomas Kailath, Prentice Hall, 1996.
- *Mathematical Control Theory* (second edition) by Eduardo D. Sontag, Springer, 1998.
- *Multivariable feedback design* by J. M. Maciejowski, Addison-Wesley, 1989.
- *The Theory of Matrices* (two volumes) by Felix R. Gantmacher, American Mathematical Society, 1960.

## **Special Assistance**

Any student who needs any special accommodations due to a disability should contact Adaptive Educational Services at (317)-274-3241. The office is located in CA 001E.