Cairo University
Faculty of Engineering

Department of Aerospace Engineering

Course Specifications

Program(s) on which this course is given:	Ph.D. program
Department offering the program:	**Aerospace engineering department**
Department offering the course:	**Aerospace engineering department**
Academic Level:	Post graduate
Date	2014-2015
Semester (based on final exam timing)	☐ Fall ☐ Spring

A- Basic Information

1. Title:	Nonlinear control			**Code:**	**AER753**		
2. Units/Credit hours per week:	Lectures	2	Tutorial		Practical		Total	2

B- Professional Information

1. Coursedescription:	The subject of nonlinear control is occupying an increasingly important place in automatic control engineering, and has become a necessary part of the fundamental background of control engineers. The objective of this course, is to present the fundamentals of analysis and design of nonlinear control systems. The scope of the course is quite broad. This is in order to show the multidisciplinary role of nonlinear dynamics and control. In particular phase plane, describing function, and Lyapunov stability theory are provided. The objective of the stability analysis is to determine the system behavior without solving the differential, or difference, equations modeling the system. In fact, the Lyapunov theory is used as a unifying medium for different types of dynamical systems analyzed. In particular, sliding mode, and chaotic controllers are all constructed with the aid of the Lyapunov method and its variants. Nonlinear control system design using both feedback linearization and sliding mode control are discussed.
2. Intended Learning Outcomes of Course (ILOs):	**a) Knowledge and Understanding**
	Different sources of nonlinearities.
	Different approaches of nonlinear control.

	Some nonlinear control techniques.
	b) Intellectual Skills
	Simulate nonlinear control systems.
	Analyze nonlinear control systems.
	Design nonlinear control systems.
	c) Professional and Practical Skills
	Use computer software packages to design, simulate, and evaluate nonlinear control systems.
	d) General and Transferable Skills
	Prepare effective and informative technical reports and present results on nonlinear control systems.
	Communicate effectively with colleagues to interchange knowledge and information in nonlinear control systems.

3. Contents

Topic	**Total hours**	**Lectures hours**	**Tutorial/ Practical hours**
1. Introduction 1.1 Why Nonlinear Control ? 1.2 Common Sources of nonlinearities Nonlinear System Behavior	3	3	
2. Phase Plane Analysis 2.1 Concepts of Phase Plane Analysis: Phase Portraits, Singular Points, Symmetry in Phase Plane Portraits. 2.2 Constructing Phase Portraits.	3	3	
2.3 Determining Time from Phase Portraits. 2.4 Existence of Limit Cycles. 2.5 Case Study	3	3	

3. Describing Function Analysis 3.1 Describing Function Fundamentals: An Example of Describing Function Analysis, Applications Domain, Basic Assumptions, Basic Definitions, Computing Describing Functions.	3	3	
3.3 Describing Functions of Common Nonlinearities.	3	3	
3.4 Describing Function Analysis of Nonlinear Systems: The Nyquist Criterion and Its Extension, Existence of Limit Cycles, Stability of Limit Cycles, Reliability of Describing Function Analysis.	3	3	
4. Fundamentals of Lyapunov Theory 4.1 Nonlinear Systems and Equilibrium Points. 4.2 Concepts of Stability. 4.3 Linearization and Local Stability.	3	3	
4.4 Lyapunov's Direct Method: Positive Definite Functions and Lyapunov Functions, Equilibrium	3	3	

Point Theorems, Invariant Set Theorems. 4.5 System Analysis Based on Lyapunov's Direct Method: Lyapunov Analysis of Linear Time-Invariant Systems, Krasovskii's Method, The Variable Gradient Method, Physically Motivated Lyapunov Functions, Performance Analysis.			
4.6 Control Design Based on Lyapunov Direct Method.	3	3	
5. Feedback Linearization 5.1 Intuitive Concepts 5.1.1 Feedback Linearization and the Canonical Form 5.1.2 Input-State Linearization 5.1.3 Input-Output Linearization	3	3	
5.2 Input-State Linearization of SISO Systems 5.3 Input-Output Linearization of SISO Systems 5.4 Multi-Input Systems	3	3	
6. Sliding Control 6.1 Sliding Surfaces 6.1.1 A Notational Simplification 6.1.2 Filippov's Construction of the Equivalent Dynamics	3	3	

6.1.3 Perfect Performance 6.1.4 Direct Implementations of Switching Control Laws			
6.2 Continuous Approximations of Switching Control Laws 6.3 The Modeling/Performance Trade-Offs 6.4 Multi-Input Systems	3	3	
4. Teaching and Learning Methods	Lectures (*)	Practical Training/ Laboratory ()	Seminar/Workshop ()
	Class Activity ()	Case Study ()	Projects ()
	E-learning ()	Assignments /Homework ()	Other:

5. Student Assessment Methods	
• **.Assessment Schedule**	**Week**
-Assessment 1;Class participation and assignment	4,10
-Assessment 2; Project Assignment	
-Assessment 3; Presentations	
-Assessment 3; Midterm Exam	8
-Assessment 4; Final Exam	14
• **Weighting of Assessments**	
-Mid-Term Examination	10
-Final-term Examination	80
Class participation and assignments	10
-Total	100

6. List of References

Jean-Jacques E Slotine, Weiping Li, "Applied Nonlinear Control", Prentice Hall,1991.

Roland S. Burns, "Advanced Control Engineering", Butterworth-Heinemann, 2001.

Stanislaw H. Zak, "Systems and Control", Oxford University Press, 2003.

7. Facilities Required for Teaching and Learning

Class room, white board, projector.

Course Coordinator:	**Prof. Gamal El-Bayoumi**
Head of Department:	**Prof. Ayman Hamdy Kassem**