

**M11 PARIS-SACLAY**  
**09/05/2022 – 13/05/2022**      *Introduction to Nonlinear Systems and Control*

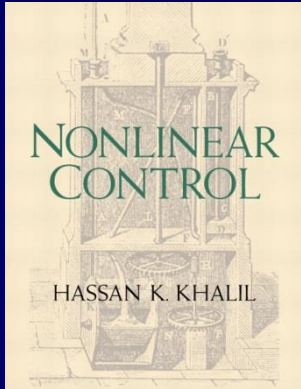


**Hassan Khalil**  
 Dept. Electrical & Computer  
 Engineering  
 Michigan State University, USA  
<http://www.egr.msu.edu/~khalil/>  
 Email: [khalil@msu.edu](mailto:khalil@msu.edu)

**Abstract of the course**

This is a first course in nonlinear control with the target audience being engineers from multiple disciplines (electrical, mechanical, aerospace, chemical, etc.) and applied mathematicians. The course is suitable for practicing engineers or graduate students who didn't take such introductory course in their programs.

**Prerequisites:** Undergraduate-level knowledge of differential equations and control systems.



**Outline**

- Introduction and second-order systems (phase portraits; multiple equilibrium points; limit cycles)
- Stability of equilibrium points (basics concepts; linearization; Lyapunov's method; the invariance principle; region of attraction; time-varying systems)
- Perturbed systems; ultimate boundedness; input-to-state stability
- Passivity and input-output stability
- Stability of feedback systems (passivity and small-gain theorems; Circle & Popov criteria)
- Normal and controller forms
- Stabilization (linearization; feedback linearization; backstepping; passivity-based control)
- Robust stabilization (sliding mode control; Lyapunov redesign)
- Observers (observers with linear-error dynamics; Extended Kalman Filter, high-gain observers)
- Output feedback stabilization (linearization; passivity-based control; observer-based control; robust stabilization)
- Tracking & regulation (feedback linearization; sliding mode Control; integral control)

# INTRODUCTION TO NONLINEAR SYSTEMS & CONTROL

## Lecture Plan (90-minute lectures)

Lecture #	Topic	Time	Textbook
1	Introduction & Two-dimensional systems	Monday 14:00 – 15:30	Chapters 1 & 2
2	Stability of equilibrium points	Monday 16:00 – 17:30	Chapter 3
3	Stability of equilibrium points	Tuesday 9:00 – 10:30	Chapter 3 & Section 4.1
4	Perturbed systems	Tuesday 11:00 – 12:30	Chapter 4
5	Passivity & Input-output stability	Tuesday 14:00 – 15:30	Chapters 5 & 6
6	Stability of feedback systems	Tuesday 16:00 – 17:30	Chapter 7
7	Special Nonlinear Forms	Wednesday 9:00 – 10:30	Chapter 8
8	State feedback stabilization	Wednesday 11:00 – 12:30	Sections 9.1 – 9.4
9	State feedback stabilization	Thursday 9:00 – 10:30	Sections 9.5 – 9.7
10	Robust state feedback stabilization	Thursday 11:00 – 12:30	Section 10.1
11	Robust state feedback stabilization	Thursday 14:00 – 15:30	Sections 10.1 – 10.3
12	Nonlinear Observers	Thursday 16:00 – 17:30	Chapter 11
13	Output feedback stabilization	Friday 9:00 – 10:30	Chapter 12
14	Tracking & Regulation	Friday 11:00 – 12:30	Chapter 13

Textbook: H.K. Khalil, Nonlinear Control, Pearson Education, Upper Saddle River, New Jersey, 2015. The global edition has the same material but with some different exercises; see <http://www.egr.msu.edu/~khalil/NonlinearControl/NoteontheGlobalEdition.pdf>