# Quick learning guide

## Dedicated systems and robotics lab

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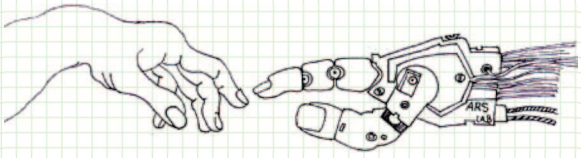
Graduate Course in Computer Science, 2014-15



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## Educational goals

To acquire and develop the following capabilities:

- model, design and optimal implementation of application-specific information processing systems
- use of harware and software tools, such as development platforms for embedded systems, to design and to implement embedded systems for robotic applications






## Course organization

The course is organized in two modules: 48-hour lecture and 24-hour robotics lab (lecture room 3, on tuesdays and thursdays, 3-6 pm)

Acquisition of the subject concepts and methods is supported by:

- attendance to lectures and problem solving
- participation to lab experiences
- study of reference readings
- consultation of supplementary readings
- experience with software tools and development platforms for embedded systems
- working out solutions to proposed problems and exercises, see Test area
- writing reports on lab experiences, in the same area
- interaction with teachers, weekly schedule:
  - G. Scollo: room 325 (I block, II floor) [phone]ext.: [095738]3007
    on mondays and wednesdays, 2:30-4:30 pm
  - C. Santoro: room M47 (III block) [phone]ext.: [095738]3001
    by appointment (via phone or e-mail)
- collaborative interaction with colleagues and teachers

## Educational activities

*Lectures:* the study of the recommended readings sets the methodological grounds for effective application of a technology-transverse, result-unitary design approach:

> versatile design of systems with optimal figure of merit that are dedicated to perform highly specialized tasks

*Exercises:* starting from a specification of the abstract functionalities of the system, the first problem which is often faced with is to select an architecture wherein to map them out, in order to further proceed to the synthesis of all components: hardware, software, communication interfaces. The proposed exercises deal with the different parts of this process.

*Robotics lab:* it is envisaged the use of development boards and platforms to implement embedded applications, ranging from on-board assembly to FPGA-based synthesis of components, up to System-on-chip (SoC) implementation. Reports on lab experiences may be outcomes of collaborative group work.

*Seminars:* as an experimental feature, some lectures (about 1/4 of the total) take the form of seminars that are prepared and delivered by students; one lecture is devoted to the planning of the seminars. Critical evaluation of the educational activities is planned in the form of a written test that is part of the final exam.






## Exams and evaluation

Oral exam, project (optional)

- evaluation objectives
- oral exam:
  assessment of the achievement of educational goals
- optional project:
  assessment of conceptual and scientific maturity exhibited in the practice of the subject
- oral colloquies
- assessment of critical learning of the subject
- evaluation of individual contribution to lab experience reports
- (optional) colloquy on individual use of subject concepts and methods within an original lab project, previously agreed with the teacher, that may be the outcome of a collaborative group effort

Exam success yields the acquisition of 9 credits.

## Lecture and Lab Program (1)

*legenda:* L = Lecture, E = Lab tutorial lecture, r = reference readings, s = supplementary readings, t.n = tutorial note #

1. Course goals and organization.
   Introduction to design of dedicated systems, codesign and embedded systems
   L01: 10/03, r: VG.01, s: LS.01
2. Architectures and design process of dedicated systems
   L02: 12/03, r: Sch.01, s: BF.01
3. Automated control systems: architectures, analysis, performance features
   L03: 17/03, r: AM.01, VG.09.1-2, s: LS.02
4. Introduction to microcontroller programming
   E01: 19/03
5. AD and DA conversion, PWM modulation, sensors, actuators
   L04: 24/03, r: M.3.1-2, M.3.6, VG.4.4, VG.4.7, s: VGM.13, Ba (t.1), BF.10.1-2, BF.13
6. LTI discrete control systems, use of the Z transform
   L05: 26/03, r: St.2.1-3, s: N.13
7. Microcontroller programming with timers and LEDs
   E02: 31/03
8. Dynamic response of discrete systems, PID control
   L06: 09/04, r: St.2.4-7, St.5.7, VG.09.3-7, s: Bi (t.2), VGM.12, We (t.3)
9. Dataflow models, control flow
   L07: 14/04, r: Sch.02, s: LS.06.3, M.2.5
10. Microcontroller programming with timers and ADC
    E03: 16/04
11. Software and hardware implementations of dataflow models
    L08: 21/04, r: Sch.03, s: Sch.04
12. Speed control of an electric DC engine
    E04: 23/04






## Lecture and Lab Program (2)

13. Design of a tilt control system by means of accelerometers
    E05: 28/04
14. Synchronous systems as finite state machines with datapath (FSMD)
    L09: 30/04, r: Sch.05.1-4
15. Hardware description languages: Gezel, VHDL, Verilog, SystemC
    L10: 05/05, r: Sch.05.5-6, Sch.A.1, s: Sch.05.7, Sch.A.2-3.1, BF.aB, M.2.7
16. Program design and analysis for dedicated systems. *Planning of student seminars*
    L11: 07/05, r: Sch.07
17. VHDL tutorial, UART example in VHDL
    E06: 12/05
18. HW/SW architecture of an autonomus mobile robot: a case study
    E07: 14/05
19. Microprogrammed architectures, System-on-Chip (SoC) design
    L12: 19/05, r: Sch.06.1-4, Sch.08, s: Sch.06.5-10
20. Hardware interfaces, communication protocols
    L13: 21/05, r: Sch.12, BF.11.1-2, s: VG.06.7-11
21. HW/SW communication, on-chip bus systems
    L14: 26/05, r: Sch.09-10
22. Example of 8-bit SoC design
    E08: 04/06
23. Microprocessor interfaces
    L15: 09/06
24. Real-time (RT): features, performance, RT operating systems
    L16: 11/06

## Recommended readings

### Reference textbooks

N.B. The recommended parts are displayed in the lecture program, for each lecture, in the short form A.C.S., where: A = initials of textbook author(s), C = chapter, S = section(s)

P.R. Schaumont: *A Practical Introduction to Hardware/Software Codesign*
2nd Ed., Springer (2012)

P. Marwedel: *Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems*
2nd Edition. Springer (2011)

F. Vahid & T. Givargis: *Embedded System Design: A Unified Hardware/Software Introduction*
Wiley (2002)

G.P. Starr: *Introduction to Applied Digital Control* (link path to textbook: Faculty / Starr / ME 581 )
2nd Ed., ME 581 textbook, Dep't of Mechanical Engineering, University of New Mexico (2006)

D. Ibrahim *PIC Microcontroller Projects in C*
2nd Edition. Newnes, Elsevier (2014)

P. Wilson *Design Recipes for FPGAs: Using Verilog and VHDL*
1st Edition. Newnes, Elsevier (2007)






## Supplementary readings

### Textbooks

C. Brandolese, W. Fornaciari: *Sistemi embedded: sviluppo hardware e software per sistemi dedicati*
Pearson, Milano (2007)

E.A. Lee & S.A. Seshia: *Introduction to Embedded Systems - A Cyber-Physical Systems Approach*
Ed. 1.5, Version 1.50 (2014)

R. Siegwart, I.R. Nourbakhsh, D. Scaramuzza: *Introduction to Autonomous Mobile Robots*
2nd Edition, The MIT Press (2011)

K.J. Åmström & R.M. Murray: *Feedback Systems: An Introduction for Scientists and Engineers*
v. 2.11b, Princeton University Press (2012) (freely available on the second author's wiki at Caltech)

N.S. Nise: *Control Systems Engineering*
6th Edition, Wiley (2011)

F. Vahid, T. Givargis & B. Miller: *Programming Embedded Systems: An Introduction to Time-Oriented Programming*
Version 4.0. Uniworld (2012)

M. Wolf: *Computers as components: Principles of embedded computing system design*
3rd Edition, Morgan Kaufmann (2012)

### Tutorials and other consultation notes

1. M. Barr: Introduction to Pulse Width Modulation, *Embedded Systems Programming* 12, Sep. 2001
2. R. Bickle: DC Motor Control Systems for Robot Applications, Jul. 2003
3. T. Wescott: PID without a PhD, *Embedded Systems Programming* 13, Oct. 2000

Any further consultation notes will be mentioned along lecture progress

## Laboratory

Lab activities take place in the framework of the ARS Lab

They consist of a series of experiences with the following topics:

- FPGA programming in VHDL
- specification and synthesis of peripheral devices (PWM, Input capture, SPI, I2C)
- servomotor control (speed and position)
- high-level control of autonomous robotic systems






## Interaction

Forum, Moodle, Galileo: what goes where?

- Forum: discussions about
  - course organization, news, FAQ
  - problems with use of on-line services, software tools etc.
  - discussions about *ideas* of dedicated system projects
- Moodle (restricted access services):
  - access to educational support materials
  - development of proposed problems and exercises
  - discussions about topics relating to lectures, lab experiences and learning materials
  - group collaboration, delivery of lab experience reports
  - discovery and discussion of possible errors in learning materials (this may award *bonus points*!)
- Galileo:
  - development of dedicated systems projects
  - documentation and dissemination of results in the public domain