Study Guide

Version 1

Industrial Automation

R7008E

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1. Introduction

Industrial Automation is a multidisciplinary subject that requires knowledge and expertise from various engineering sectors, such as electrical, electronics, chemical, mechanical, communications, process and software engineering. Nowadays the application of Industrial Automation has been transformed to a ubiquitous infrastructure that automates and improves the human life in all the everyday activities. Characteristic examples of industrial automation systems can be found in the car industry, the aviation sector, the marine industry, the health systems, the transportation sector, in the electrical power production and distribution, in the pulp and paper industry, and many other numerous applications, which are making our society so dependent on automation that it is difficult to imagine how the life would look like without automation engineering.

The R7008E-Industrial Automation course, with 7.5 HE credits, at Luleå University of Technology and the Department of Computer Science, Space and Electrical Engineering Department, is an obligatory course in the Computer Science Master Program on System Automation and is being provided in LP4 of each year.

The aim of the course is to provide an extended overview and fundamental knowledge in the field of Industrial Automation, while building the necessary knowledge level for further specialization in advanced concepts of Industrial Automation. For achieving this objective, the main focus and teaching model of the course is the learning by constant hands on experimentation and problem solving from real life examples. More specifically a series of lectures will be combined with experimental laboratory assignments (small scale setups), and automation problem solving from real life applications.

The course has been designed for both undergraduate and graduate students, while the expected learning outcome is the ability for an engineer to: a) understand basic concepts in the industrial instrumentation and actuation field, b) design, synthesize and implement classical industrial automation systems (relay based), and c) get familiar with the PLC based industrial automation systems. The provided knowledge and the achievement of the learning objectives will create the fundamental engineering background for dealing with applications in the Industrial Sector.

2. Intended Learning Outcomes

After taking this course you should be able to:

- **Understand** the functionality of basic elements of automated systems and the fundamental principles of operation
- **Analyze** a real life problem from an industrial automation perspective, understand what is effective, what is not, judge based on an engineering and cost oriented thinking
- **Identify and Select** proper sensory and actuation equipments for synthesizing and integrating industrial automation tasks
- **Integrate and Synthesize** a classical relay based industrial automation

- **Integrate, Synthesize and Program** a PLC based industrial automation
- **Design** a PCB based Industrial Automation
- **Analyze, Integrate and Combine** Electro Pneumatic-Hydraulic Automation with relay or PLC based industrial automation
- **Gain fundamental knowledge** Industrial Networks and PID control in the Industry

3. Preliminary knowledge

Preliminary knowledge for the course is basic understanding of concepts in: a) electrical circuits' laws, b) Boolean logic, c) physics, and d) basic programming concepts. However, before the introduction of new concepts, a short overview of the basic knowledge needed will be provided where necessary.

4. Course activities

The course activities are being separated between attending lectures, conducting laboratory work, home task assignments, and problem solving sessions.

4.1 The areas that the lectures will cover are:

1. **Introduction to Automation**
    - **a.** Basic elements of an automated system
    - **b.** Levels of Automation
    - **c.** Process Industries
    - **d.** Continue Versus Discrete Control
    - **e.** Computer based Process Control
2. **Hardware Components for Automation and Process Control**
    - a. Sensors
    - b. Actuators
    - c. Relays
3. **Industrial Automation Synthesis**
    - a. The Latch principle
    - b. Step by Step basic Automation Examples synthesis
        - i. Motor operation with thermal protection
        - ii. Automation Signaling for fault representation
        - iii. Machine operation with starting delay
        - iv. Machine operation with stopping delay
        - v. Periodical Machine operation with two time constants
        - vi. Machine operation from multiple control points
        - vii. Sequential start – Chain Latching
        - viii. Motor operation with power supply from two power networks

   c. Motor Automation Synthesis
      i. Start/Inverse motor operation
      ii. Star/Delta Change over motor operation
   d. Industrial Automation with Sensor devices
      i. Machine start with canceling option
      ii. Level Control Pump operation
      iii. Demand based Level Control of two pumps
      iv. Garage Door Automation
   e. Regulation for designing Industrial Automations
      i. Low and High Voltage Control circuits design
   f. Applications
      i. Integrating Machine control from multiple control points
      ii. Power Transformer Control
      iii. Two Pump Control with circular
      iv. Automation of a hydraulic down acting ingle cylinder type press
      v. Quality inspection

4. **Logical Design of Industrial Automation**
   a. Boolean logic
   b. State Machines
   c. Applications
5. **Basic components of Electro pneumatic Automation**
   a. Pneumatic Devices and Principles of Operation
   b. Pneumatic Valves
   c. Electro pneumatic Automation
   d. Applications
6. **Industrial Networks**
   a. Overview of Industrial networks & principles
7. **Basic Programming Principles of PLCs**
   a. Introduction to PLCs (Hardware)
   b. Introduction to PLCs (Software)
   c. Examples
8. **PID control in the Industry**

4.2 Laboratories (2.5HP)

4.2.1 The Latch Principle

Lab 1 Objectives

- Understand the Latch Principle
- Understand the operation and the characteristics of a Relay
- Understand the operation of NO and NC contacts of a push button
- Build an automation for ON/OFF controlling the operation of a light
- Get basic training in wiring and building industrial automations

Lab 1 Description

The aim of the lab is to get practical experience in building automations with relays in a typical application of controlling the ON/OFF operation of a light by pressing a START and STOP button. The students should build the automation by utilizing the following items:

- Breadboard and cables
- Solid State Relay
- Light
- A START and STOP button

4.2.2 Conveyor Belt Control

Lab 2 Objectives

- Get experience with a more a complicated Industrial Automation
- Utilize and get training in wiring and building industrial automations with a large number of relays
- Utilize limit switches and integrate them in the automation scheme

Lab 2 Description

The aim of the lab is to design an Industrial Automation for controlling the movement of a conveyor belt. The control of the movement will be made by appropriate direction control of a DC motor. During the movement, limit switches will be integrated to signal the end of directional movements (safety) or signal the automatic operation of the conveyor belt. The students should build the automation by utilizing the following items:

- Breadboard and cables
- Solid State Relays
- Light indicators
- LEFT and RIGHT buttons
- 2 Limit Switches
- DC Motor
- Conveyor Belt Setup

4.2.3 PCB based Industrial Automation Design

Lab 3 Objectives

- Get experience with the design of industrial automations for massive production based on the Printed Circuit Board (PCB) design technique
- Understand and practice with different real life design based design criteria such as: cost of the design, simplicity in the manufacturing, effective routing, non-desirable designs, etc.
- Utilize EAGLE software for designing the electrical schematic and creating the PCB

Lab 3 Description

The aim of the lab is to exercise the students with the utilization of a PCB design software, like the EAGLE software, in order to be able to produce PCB based industrial automation solutions for massive productions. During the Lab Mr. Dariusz Kominiak will provide an interactive seminar for the students where he will demonstrate the completion, with the PCB approach, of the Lab 1 assignment, while demonstrating the basic functionalities and capabilities of the EAGLE software. In the sequel, it will be requested from the students to complete as a home assignment the solution to the problem specification from Lab 2 with the PCB design method.

EAGLE is a software that has a free downloadable version that all the students can download and install in their personal computer.

4.2.4 PLC based Industrial Automation

Lab 4 Objectives

- Get experience with the programming environment of a Programmable Logic Controller (PLC)
- Utilize Ladder and the PLC to solve an Industrial Automation problem
- Understand the basic operational principles and fundamental components of a PLC

Lab 4 Description

The aim of the lab is to utilize a PLC for controlling the operation of a traffic light. This traffic light is equipped with three indication lights (Red, Orange and Green) and the students by the utilization of the provided PLC should construct software that will be able to: a) switch on the red indication for 5 sec, b) switch off the red indication and switch on the orange indication for 0.5sec, c) switch off the orange indication and switch on the green indication for 5 sec, d) perform the same operation after waiting for 10 sec. The correct operation of the software should be demonstrated with the provided PLC and the experimental setup of the traffic light.

5. Submission of Assignments

Assignments are submitted in Fronter. There is a room for the course and related folders for of the requested assignments. In case that you cannot meet the time line and you are making a late submission then you will not be able to submit it into the correct folder and thus the report should be submitted in the Late Assignments folder.

6. Course Examination and reporting

The grade of the course is a combination of the following categories, with the indicated percentages:

- **(5 Credits – U, B, VG Grade) Written examination** where the student should be able to demonstrate the knowledge gained in designing industrial automation setups. A real life problem will be analyzed and the student should provide a proper solution based on industrial automation principles.
- **(2.5 Credits – U G grade) Accomplishment of the required laboratory assignments –** No reporting is needed. The accomplishment of the task will be based only on demonstration of the students' solution and a grade will be only pass or fail. The students can be categorized into groups, depending on the total number of students attending the course.

  The laboratory sessions are compulsory, except by arrangement with the teacher. There are tight deadlines on the assignments and the teacher and assistants are at these sessions specifically to assist students who are having problems.

7. Course literature

Selection of sections from the following literature:

Text Books

[T1] Mikell P. Groover, "Automation, Production Systems and Computer-Integrated Manufacturing", Pearson International Edition, 2013. ISBN:9780132070737

[T2] Mark Newman, "Networks: An Introduction", May 20, 2010, Oxford University Press, ISBN: 9780199206650

[T3] SIEMENS, "Working with Step 7 – Getting Started", Edition 03/2006. The online version of this document can be located at: http://support.automation.siemens.com/WW/llisapi.dll/csfetch/18652511/S7gsv54_e.pdf?func=cslib.csFetch&nodeid=18653849&forcedownload=true

Lecture Notes

[L1] G. Nikolakopoulos, "R7008E - Industrial Automation Lectures", Luleå University of Technology, available in the Fronter R7008E course room.

8. Course credits

Passing the course awards 7.5 ECTS.

9. Plagiarism

Plagiarism is a form of cheating. It is taking and using someone else's thoughts, writings or inventions and representing them as your own; for example, using an author's words without putting them in quotation marks and citing the source, using an author's ideas without proper acknowledgment and citation, copying another student's work. If you have any doubts about how to refer to the work of others in your assignments, please consult your lecturer or tutor for relevant referencing guidelines.

The intentional copying of someone else's work as one's own is a serious offence punishable by penalties that may range from a fine or deduction/cancellation of marks and, in the most serious of cases, to exclusion from a unit, a course or the University. All of your reports will be automatically analyzed by a plagiarism control software called Ephorus. Your reports will be automatically compared against the work of previous students, the work of the other students in the class, and material on the internet. This software detects copied pieces of text and will report this and where it is copied from to the Lecturer.

10. Course Plan

Lecture #	Lecture's Content	Suggested Reading Materials
1	Introduction to Automation	[T1] Chapter 1
2	Hardware Components for Automation and Process Control – Part A	[T1] Chapter 2
3	Hardware Components for Automation and Process Control II – Part B	
4	Industrial Automation Synthesis – Part A	[T1] Chapter 3
5	Industrial Automation Synthesis – Part B	
6	Logical Design of Industrial Automation	[T1] Chapter 4
7	Basic Components of Electro Pneumatic Automation – Part A	[T1] Chapter 5
8	Basic Components of Electro Pneumatic Automation – Part B	
9	Basic Programming Principles of PLCs	[T1] Chapters 6 and 7
10	PID Control in the Industry	[T1] Chapter 9
11	Industrial Networks	[T1] Chapter 8