



# University of Mosul College of Engineering Mechatronics Department



## Automation Lab

### Introduction

Automation laboratory in the Mechatronics Engineering department was founded in 2006 as well with initial establishment of the department. This lab was provided with most of the essential equipment from international manufactures and distributaries in the period of 2008 to late 2010. The infrastructure of the automation lab was designed to serve the objectives of the lab (to be explained later,) so as to serve students before graduation, and the engineering community in the field of interest after graduation. Principally, automation lab provides the undergraduate students with the basic and intermediate levels of knowledge required in industrial production factories where modern controller is used in the field to provide process automation. Additionally, it deals with the use of CNC machines in the field of manufacturing.

### Why We Need to Develop and Upgrade the Hydraulic Lab?

Automation lab experiments principally support the curricula of the automation subject given to the fourth-year students. Automation subject is in the heart of the mechatronics engineering field. It makes the engineer to understand how modern factories controlled and work where industrial processes are intelligently controlled to get the best product both in quantity and quality basis. To do its function, automation lab includes three sections of equipment. These are the fluid power systems (Pneumatic equipment), the PLC controller training, and the CNC programming section. The apparatus in the fluid power section aims to simulate the real industrial and manufacturing processes in industry, and how these processes are controlled. These processes such as material handling, testing, sorting, machining and so on. The PLC section aims to introduce students to the PLC programming and use as an industrial controller. Due to last war in Mosul, sections in this lab was damages on various levels. In the fluid power system, there is a partial damage happens. This affects the modeling and simulation section of industrial processes. In the PLC part, only one industrial PLC component still available while others are lost. These PLCs not only used in the automation lab, but also, in the final year graduation projects. Unfortunately, the CNC equipment's were lost fully.

Therefore, there is a big lack in the CNC branch that need to work on. **Benefits and applications of CNC machines in working field**

### Location, Dedicated Area for The Equipment and Integration with Other Labs

Automation lab has its own room and belongs to the mechatronics engineering Department. Precisely, it is in the ground floor of the 2<sup>nd</sup> building (building on the right-hand side after getting in the main department door). Mechatronics engineering department laboratories, including the automation lab, was not given any rehabilitation process yet. All the repairs done are due to simple efforts from some department faculty members. The figure below shows the layout of the lab with actual dimensions in meters.

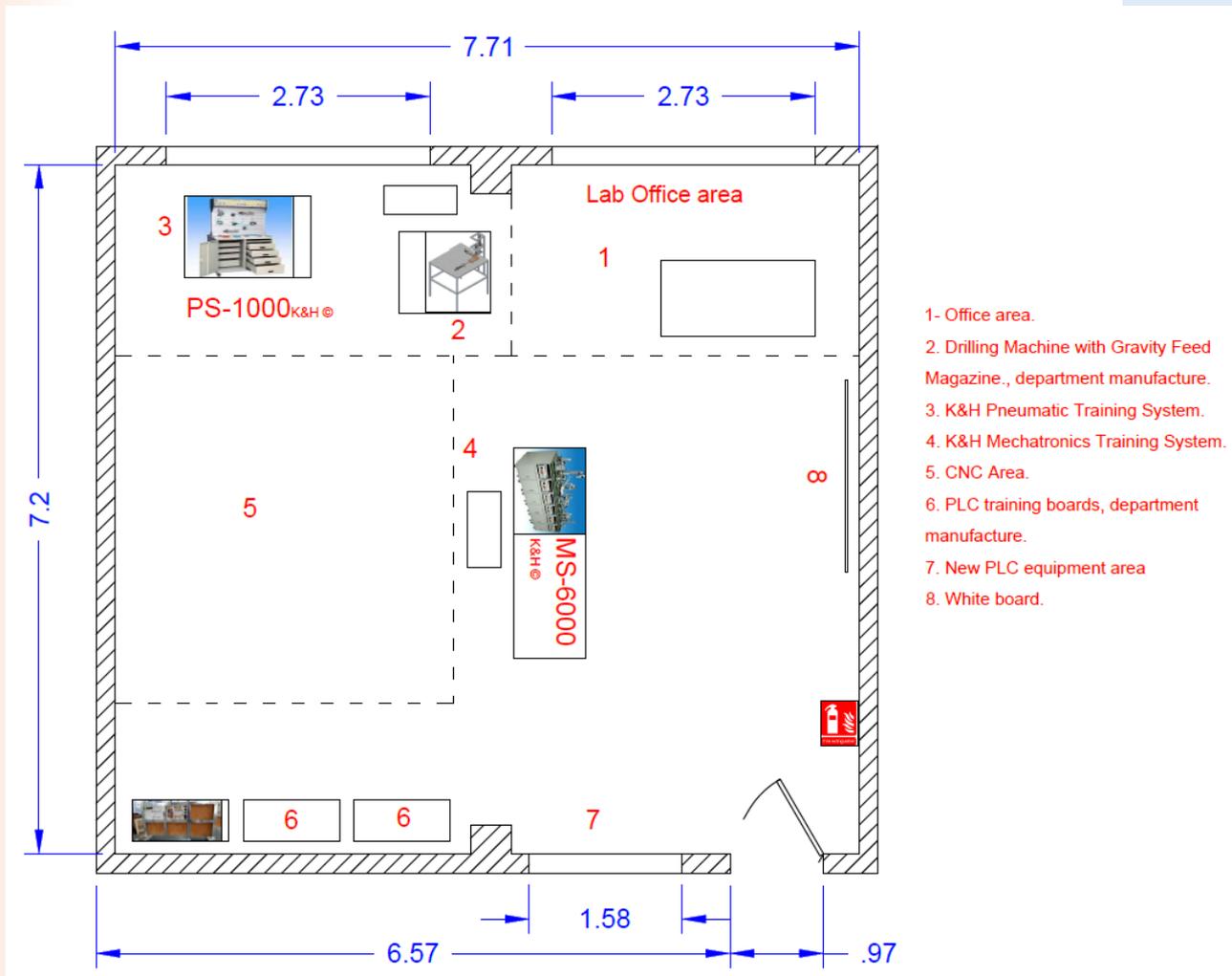


Figure 1: Automation Lab Layout.

The total area of the lab is about 56 m<sup>2</sup> in which is all dedicated to the experiments setups occupies about 35 m<sup>2</sup>. There are four places in the lab: first one assigned to the lab supervisor office (area 1).

The other area is for the Pneumatic systems area which includes three apparatus (areas 2, 3, 4.) third place is for CNC machines which need to be reestablished after it lost in the final war (area 5). The fourth place is assigned to the PLC training board where there is an empty space (area 7) available for development of PLC training purposes. In term of integration and synergies with other labs, we have robotics, measurements, simulation, workshop, and control labs in mechatronics Engineering Department. The following table summarize these integrations:

*Table 1: Interrelations between Automation lab and other labs in Mechatronics Engineering Department.*

No	Lab	Integration with the automation lab
1	Robotics	When the movable arm(s) in automation process are required to be designed on the basis of dynamic movement, and weight that can be handled, the robotic lab stand here.
2	Control	The automation and control labs are interconnected in the design of controllers. Basically, PLC is representing the main junction here.
3	Measurement	Any industrial process control needs a feedback of signals to get accurate movement, material fault/flaw finding, quantity and quality measures. All these feedbacks are sent to the PLC through the use of sensors and actuators which are introduced in the measurement lab.
4	Simulation	It is in the future plan of the development of automation lab, is to simulate the processes those can be done with the lab various apparatus using suitable softwares, like FESTO FluidSim, Automation Studio, PLC programming software. These softwares simulation need to be done on suitable PCs in the computer lab.
5	Workshop	4 <sup>th</sup> class graduation projects usually need to manufacture some parts in the workshop. However, when the manufactured parts need to have sophisticated details and some challenging details, usual workshop machines (60% lost in the last war) are not suitable. In such situations, we were using the CNC machines in the automation lab. This adds another benefit of these CNC machines in addition to the supporting of curricula of the automation subject.

### **Curricula of the Automation Lab**

In our department, we have the automation subject offered to the final year students. This subject is only offered in our department out of all the engineering departments in both University of Mosul and Ninawa University. Accordingly, this subject needs a strong supporting experimental work to give the students a versatile knowledge that he/she will face in the real engineering life after graduation. Accordingly, the objectives and learning outcomes of the lab are:

- Automation laboratory objects to introduce undergraduate students to the latest technologies in real industrial processes and their control in a modern factory.
- Introduces students to the real implementation of the sensors and actuators technologies in the industry field.
- PLC use is introduced to students as a state-of-the-art industrial controller.
- Gives students the ability to use modern CNC machines and how to prepare the CAD drawing and G-code used to program them.

Basically, all of the automation lab experiments in our department are offered for the undergraduate students during the fourth year of their study during the study of the automation subject and doing fourth class projects. Additionally, it is related to the mini-projects implemented by the third and 2<sup>nd</sup> class students. Additionally, 1<sup>st</sup> year students are in need to learn the manufacturing processes. They get this knowledge in both workshop and CNC section of the automation lab. In the following, we summarize the learning objectives of each apparatus:

1. **Fluid Power systems (Pneumatic training system PS-1000):** It allow to design and simulate pneumatic systems with all types of control (manual-pneumatic-electric-plc digital control. Also, give students a knowledge on how sensors and actuators use in production process control.
2. **CNC Lathe, milling, & laser Cutting machines:** introduces students to part programming. Students will learn the commands that create the movements of the machine tool — including those for rapidly positioning and repositioning tools as well as those for straight line moves and movements along an arc at controlled machining speeds. Additionally, students will learn the commands to set the spindle rotation direction and RPM. Both machines give students the knowledge for part machining having 2D, or more complex motion. Even, those machines are used together with the department workshop for manufacturing final graduation year projects, as well as, manufacturing components in Mosul industrial field.
3. **PLC training board:** Its function is to learn student what is the internal functions of the PLC, how to use it step by step, learning the available PLC programing methods, and integrate it with various sensor and actuator to achieve the PLC-based automation system. It can provide students with a thorough understanding of the theories and applications of programmable logic controllers. This trainer enables students to learn step by step from the fundamentals of PLC to more advanced controls used in industry.
4. **Apparatus with combined benefits from the above**
  - a. **Mechatronics system:** It allows varying simulation of real production processes that exist in industry field, so, students can learn the entire process of production. These processes are:

Distributing, Testing, Processing, Handling, Assembly and Storing stations that can be operated separately or integrally. Learning contents are Mechanic automation, PLC program development, Sequential control, Installation diagnostic, Pneumatic Drives, Electronic, Industrial safety, sensors and actuators use in production process control.

- b. **Drilling machine with gravity feed magazine:** It is 4th class project (designed and implemented completely by students) to simulate the automate the drilling process of a wood parts. Its process control is using PLC, with all parts are bought from domestic resources. It serves to learn students how to use PLC controller, design & building pneumatic systems from scratch. Able for further developments like adding sorting and packaging processes. Also, give students a knowledge on how sensors and actuators use in production process control.

### teaching objectives of the Automation Lab

#### Section 1: PLC controllers

The programmable logic controller (PLC) lab. will contain multiple work stations which include the plc training board and computer to train the students how to design a ladder diagram, program it, upload it, and run various systems includes automatic operation like traffic light, conveyer belt, water level, etc...

The students use the GX work2 as ladder programming environment for simulation, uploading and running the codes. Currently The lab based on Mitsubishi FX1N-20MR industrial programmable logic controller. In the following, are a list of experiments of the PLC section related to the automation lab:

1. **Introduction to fx-1n 20mr PLC:** I/O types, Addressing, possible configuration, Timer/Counter address, and programming language.
2. **Introduction to GX-Work 2 development environment:** first time running, making a new project with proper PLC, simulation and upload to the destination PLC.
3. **Reading form switches:** (Normally Open push, Normally Close push Button, Toggle Switch, Emergency Switches, Start/Stop Switches, Limit switches). The ladder diagram uses to read these switches from a specific input address, apply lock/interlock mechanism, and translate this signal into specific output address.
4. **Controlling the output relay** ( turn on various indicators in the board
5. **Logic gates programming using ladder diagram** (logical AND, OR, NOT, and XOR)
6. **Combination logic programming using ladder diagram**

7. **Normal traffic light**(using various timers, output address to achieve the required sequencing for traffic light)
8. **Adaptive Traffic light with pedestrian button**(using extra input, timer delay adaptively when there is a pedestrian in the traffic zone)
9. **Automatic conveyor belt**: proximity switch reading for item detection, conveyor belt axis limit to limit the motor operation, emergency switch for emergency stop, control the conveyor belt motor direction to achieve the automatic control of the transporting over the belt.
10. **Three phase motor direction control**: controlling two contactors to achieve the 3-phase motor control, adding the time which is works between direction exchange for safety, and emergency sw.
11. **Simple HMI**: adding an extra HMI to display Numbers and/or get input from HMI panel.
12. **Water level control**: automatic filling/dispenser of the tanks to control the liquid level between two tanks, which includes: level sensors, flow sensor, solenoid valve, and water pump.
13. **Elevator control**: control the elevator properly according to the request which includes: external panel buttons, internal passenger cabin buttons, passenger cabin floor position, and motor control.
14. **Automatic car parking**: the plc counter uses to specify the number of cars inside the parking area and to control the input gates, output gates according to the available parking positions.
15. **Induction motor speed Control**

### Target population

Today, the automation lab in the Mechatronics Engineering Department serves at least about 100 students each semester from our department only. Additionally, this lab is the only one of its kind in all the educational institutions in Mosul city. Therefore, it is expected that the population engaged with this laboratory will increase in the foreseen future both on staff and students' levels. The number of Mechatronics department professors, researchers and engineers that involve in the automation lab work may be classified as follow:

- No. of Professors and lecturers in automation field from our department = 3.
- No. Engineers and Technicians from our department = 3.

The weekly schedule of our automation lab for this academic year is shown in the table below.

*Table 2: Weekly Schedule of the Automation Laboratory.*

Day	8:30-10:30	10:30-12:30	12:30-2:30
Sunday	Maintenance		
Monday	2 <sup>nd</sup> & 3 <sup>rd</sup> class – mini-projects		4 <sup>th</sup> class – automation
Tuesday	4 <sup>th</sup> class – final year project		
Wednesday	2 <sup>nd</sup> & 3 <sup>rd</sup> class – mini-projects		4 <sup>th</sup> class – automation
Thursday			

### **Role of automation lab for our department alumni and engineers who work at Mosul city facilities and infrastructures**

The automation lab provides various professional outcomes to those students graduating from our department and other relevant engineering departments by preparing students for engineering experience, principle of design and practice. In particular, our department alumnus involves in design and management of very important facilities and infrastructures, such as electrical power plants, industrial projects, laboratories for ministry of health, automatic production lines in factories. Following, are examples of employment opportunities in the aforementioned fields:

1. In Directorate of Mosul Dam, Mechatronics department alumni are working in the electric power generation units, where the undergraduate subject those serve them in this field are both control and digital control (microprocessor controllers), electric circuits, electric machines, fluid mechanics, thermodynamics, and engineering measurements subject.
2. Related to the Directorate of electric power Distribution Network in Nineveh, graduates work in the sector of electric power generation. Specifically, control of power generation. Electric machines, electric circuits, thermodynamics, and engineering measurements are the most related topics those build a confidential background of our department alumni works in these fields.
3. Northern cement cooperative in Nineveh, Cement factory also benefit from our lab in production line. Specifically, in the filling lines of 20kg packs line. Similar factories are in need for such automation knowledge as they have such production line. These are dairy, medicine, and steel factories. Those are in need to new and more automated and efficient lines.

4. Within health sector, automation labs CNC machines will be useful to manufacture mould of plastic containers in medicine factory in Mosul, in addition to medicine packaging lines.
5. Private companies of cell-phone companies: here graduated student getting benefits from the computer aided drawing (1<sup>st</sup> year) to draw 3D network bridges and also the laser and communication subject (4<sup>th</sup> year).
6. Manufacturing (machining) of specimens used to test materials in tensile test. Those for factories and postgraduate student projects. Where the local industry cannot produce such complex configurations.
7. Pure water, choice production, medical, and some other plastic related factories in Mosul city can benefit from our lab CNC machines as those machines can produce mould of plastic containers.
8. In our city we have two big amusement parks and more than 10 with limited area. The creativity of our students mixed with the lab gained experience will definitely push our student to get jobs on amusement parks maintenance and development.

In all these sectors and directorates, understanding the control of mechanical and electrical parts and the process automation as they practically offered by our lab tend to be the platform of engineers to start with their careers in our societies. Where this lab provides a great opportunity to verify popular theories in field of engineering that learned in class.

### **Teaching approach**

The lab is designed to provide the student with a physical understanding of the fundamental principles and basic equations of process automation, control, and CNC machining. This understanding is gained through the application of lecture concepts and equations to real industrial processes. Practically, designing and applying electronic control circuits to satisfy the requirements of each process available is implemented in the lab. These processes are part selection, handling, machining, sorting, and testing. Even, we have electronic PLC simulating board designed by personal effort which help to understand internal operation and connection of real industrial PLC devices. Additionally, G-code programming is used to operate the CNC machines used for manufacturing.

## Equipment

The automation lab in mechatronics engineering department is not working with its potential functions due to lack of essential equipment and being most of the setups were lost during the liberation of Mosul on 2017. In the following table, we summarize the equipment in the lab and their current situations, together, with the plans of repair. It is observed that all the following machines are serving the above objectives of the lab, and giving the mechatronics graduates the required knowledge in the field.

*Table 3: List of the essential equipment for under-graduate students.*

No	Apparatus	Original fund provider	Current situation	Its plan
1	Mechatronics system	Iraqi Government	Not working. Frame and main parts survived	Repair through department labs policy
2	Pneumatic training system	Iraqi Government	barely working. Frame and most of the parts survived	Repair several lost parts + purchase others which cannot be repaired/designed by our staff
3	CNC lathe machine	Iraqi Government	Lost	Purchase new machine ~ \$5000
4	CNC laser cutting machine	Iraqi Government	Lost	Purchase new machine, ~ \$5000
5	CNC Milling machine	Iraqi Government	Lost	Purchase new machine, ~ \$5000
6	PLC training system	Department work	Available	Completing the build of several models to serve many groups of students. through department labs policy

7	Drilling machine with gravity feed magazine	Department work	Not working. Frame and main parts survived	Repair through department labs policy
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As we mentioned in the previous sections, the automation lab in our department is not working with its potential functions due to lack of essential equipment and being most of the setups are missing. According the need, we prepared three lists of equipment as essential and desirable that we believe reasonably match the lab goal and syllabus, target population and teaching approach. Each list is related to the three sections of the automation lab, namely, Pneumatics, PLC, and CNC sections. In the below, we present the list related to the PLC section.

*Table 4: List of the essential equipment for undergraduate students.*

No.	Item	Recommended no. of units	Estimated Unit price(US\$)	supported* experiment population	Student population	Related Labs.
1	Siemens PLC- LOGO! 12/24RCE	5-6	150-180	3-10,12-14	110	Automation
2	Siemens LOGO! DM8 12/24R expansion module	5-6	65-80		80	
3	Siemens LOGO! AM2 AQ expansion module	5-6	75-100		80	
4	SIEMENS LOGO! Soft Comfort V 8.2	2	60		110	

5	Starter-Kit CPU 1212C + KTP700 Basic Siemens S7-1200 - 6AV6651- 7DA01-3AA4	2	900	15	80	Automation + Control
6	Siemens SM 1231 AI - 6ES7231-4HD32-0XB0	2	220		80	
7	SINAMICS V20	2	250			

\* see the section of teaching objectives for the related numbers of PLC experiments.

Note: regarding Festo PLC Training Board, we found that there are several modules available online. From our side, any board that cover the above fifteen experiments will be suitable for us.