

Festo Modular Production System (MPS)

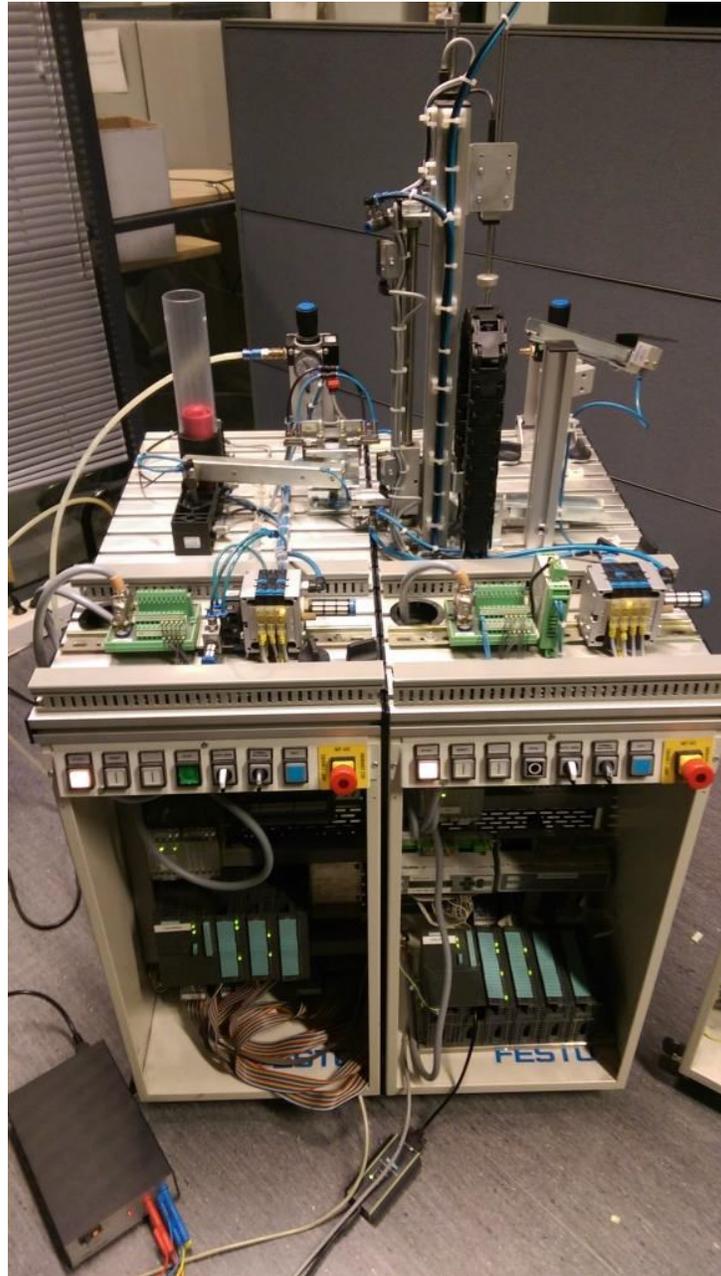


Figure 1 Distribution station (left) and testing station (right)

1 Introduction

The purpose of this document is to describe the distribution and testing stations of the Festo MPS (Figure 1), which you will model on this course using SysML after getting some hands-on training with this equipment. Festo is a leading company in the automation industry, especially in the area of mechatronics. Its line of didactic products, is extensively used in industrial vocational training, research and teaching around the world. MPS is a lab-scale production line simulating the functions that may be identified in a factory such as distribution, testing, processing, handling, assembly, and storage.

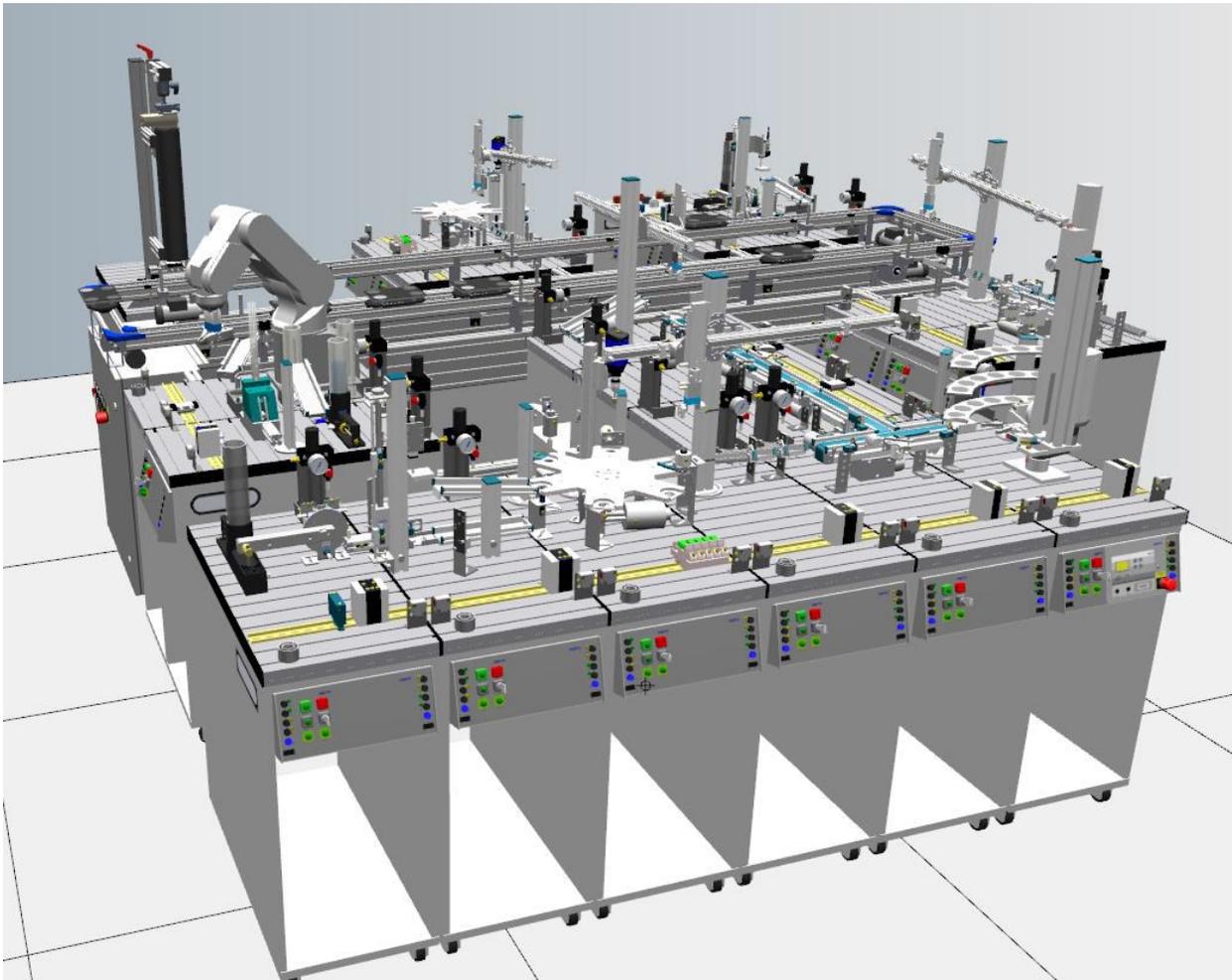


Figure 2 MPS workstation forming a complex production line. The distribution and testing stations in Figure 1 are on the left in the foreground

Siemens' family of SIMATIC S7 PLCs are considered to be the most widely used PLCs in the industry. The PLCs in Figure 2 are of type S7-314, and can be extended with IO terminal modules that enable the PLC to be connected to sensors and actuators. The following figure shows the PLC on the distribution station equipped with 3 Digital input/output (DIDO) modules, each with 8 inputs and outputs connection.

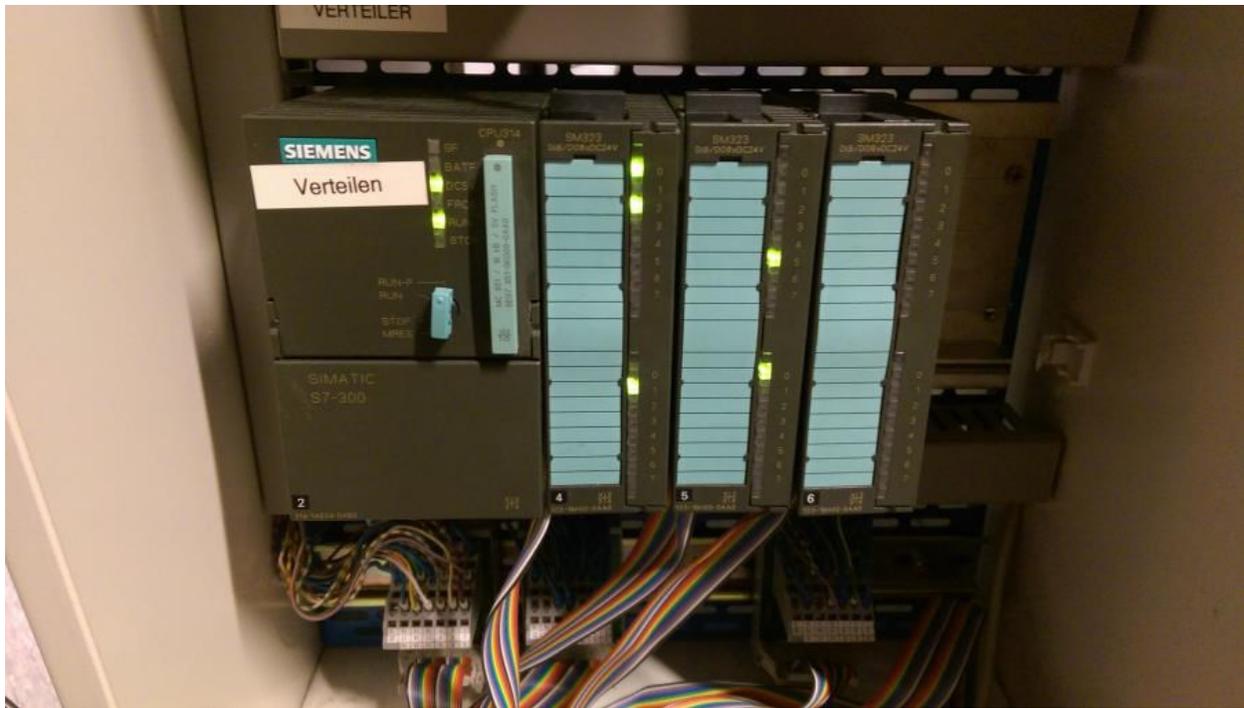


Figure 3 Siemens S7-314 PLC with three DIDO modules

2 The distribution station

2.1 Overview

The distribution station is a feed device with storage function. It provides the input material or “workpiece” into the system so that other functions such as drilling and testing, provided by other stations in the system, can operate on the workpieces. The function of the distribution station can be summed up as follows:

- To separate out workpieces from the stack magazine by pushing the bottom one out with a piston
- To transfer workpieces to a downstream station by means of a changer module with a rotary arm with a pneumatic suction cup.

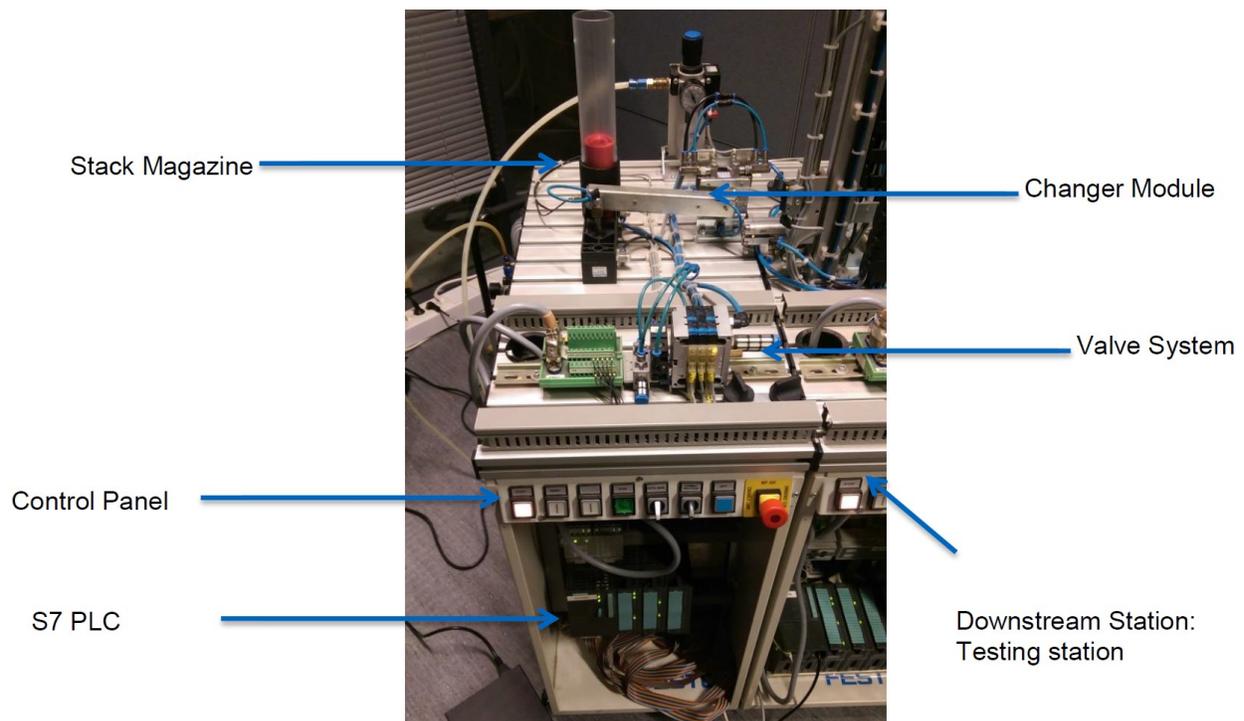


Figure 4 The distribution station

2.2 Stack magazine module

The magazine barrel of the stack magazine holds up to 8 workpieces. The workpieces must be inserted with the open side facing upwards. A double acting cylinder pushes the lowest workpiece from the gravity-feed magazine up to the mechanical stop. This position serves as a transfer point to the changer module. The availability of workpiece in the magazine barrel is monitored by means of a through-beam sensor. The position of the ejecting cylinder is sensed electrically via inductive sensors. The advancing and retracting speed of the ejecting cylinder is adjustable by means of one-way flow control valves.

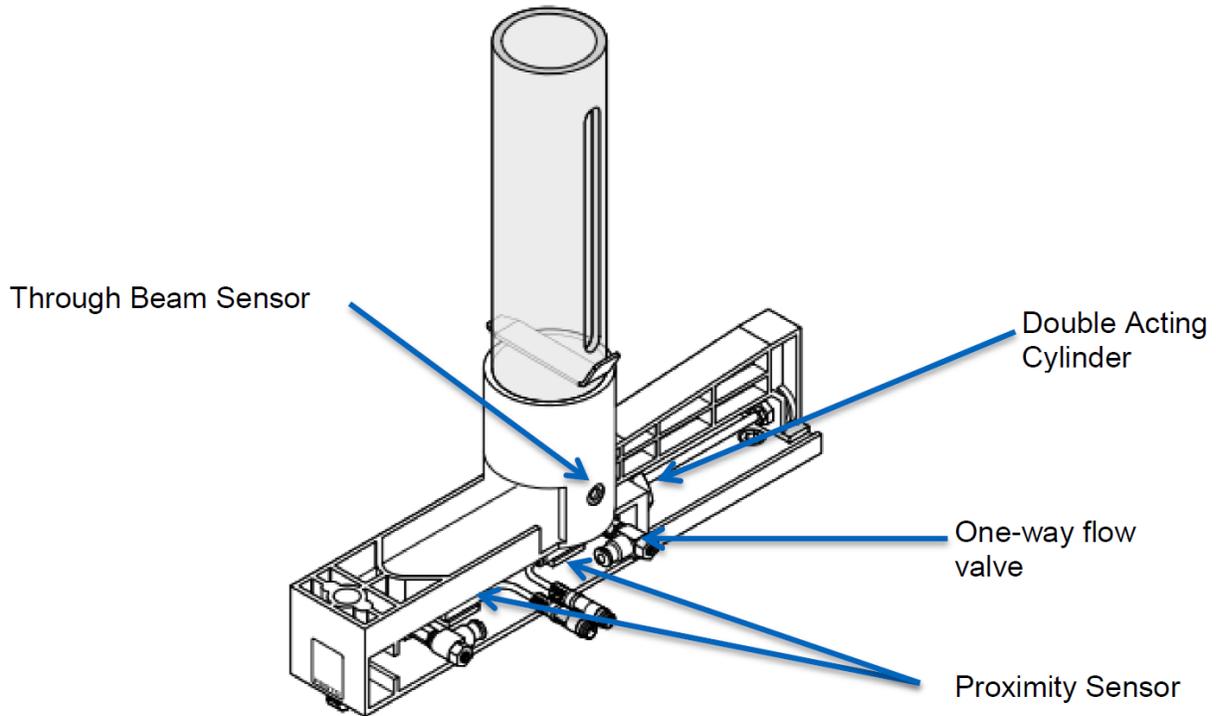


Figure 5 Stack magazine

Before we describe the components, note first the following basic definitions of cylinders. The fluid is air in case of pneumatic equipment and liquid in case of hydraulic equipment. In this case study, there is no hydraulic equipment. The forces that need to be generated are small so there is no need for hydraulic equipment.

- **A single-acting cylinder** is a cylinder in which the working fluid acts on one side of the piston only. A single-acting cylinder relies on e.g. the load or springs to push the piston back in the other direction.
- **A double-acting cylinder** is a cylinder in which the working fluid acts alternately on both sides of the piston. In order to connect the piston in a double-acting cylinder to an external mechanism, such as a crank shaft, a hole must be provided in one end of the cylinder for the piston rod and this is fitted with a gland or 'stuffing box' to prevent escape of the working fluid. A double-acting cylinder is used where an external force is not available to retract the piston or where high force is required in both directions of travel.

No	Part Name	Description
1	Proximity Sensor	End position sensing of the ejecting cylinder.
2	Through Beam Sensor	Optical Sensor. Monitor the availability of workpieces in the magazine barrel
3	Double Acting Cylinder	Pneumatic actuator, double acting, with magnet ring for position detection. Pushes the workpiece out from the magazine barrel to the transfer point for the changer module to pick up.

4	One-way flow control valve	Flow control valves to adjust the piston rod speed
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2.3 Rotary drive module

The rotary drive module is a pneumatic handling device. It grips the workpiece that has been pushed out of the magazine by using a vacuum enabled suction cup. A vacuum switch checks whether a workpiece has been picked up. The arm of the transfer unit, which is driven by a rotary drive, conveys the workpiece to the transfer point of the downstream station (i.e. testing station in Figure 1). The swivelling range is adjustable between 90 degrees and 270 degrees by means of mechanical end stops. The end position sensing is effected by means of electrical limit switches.

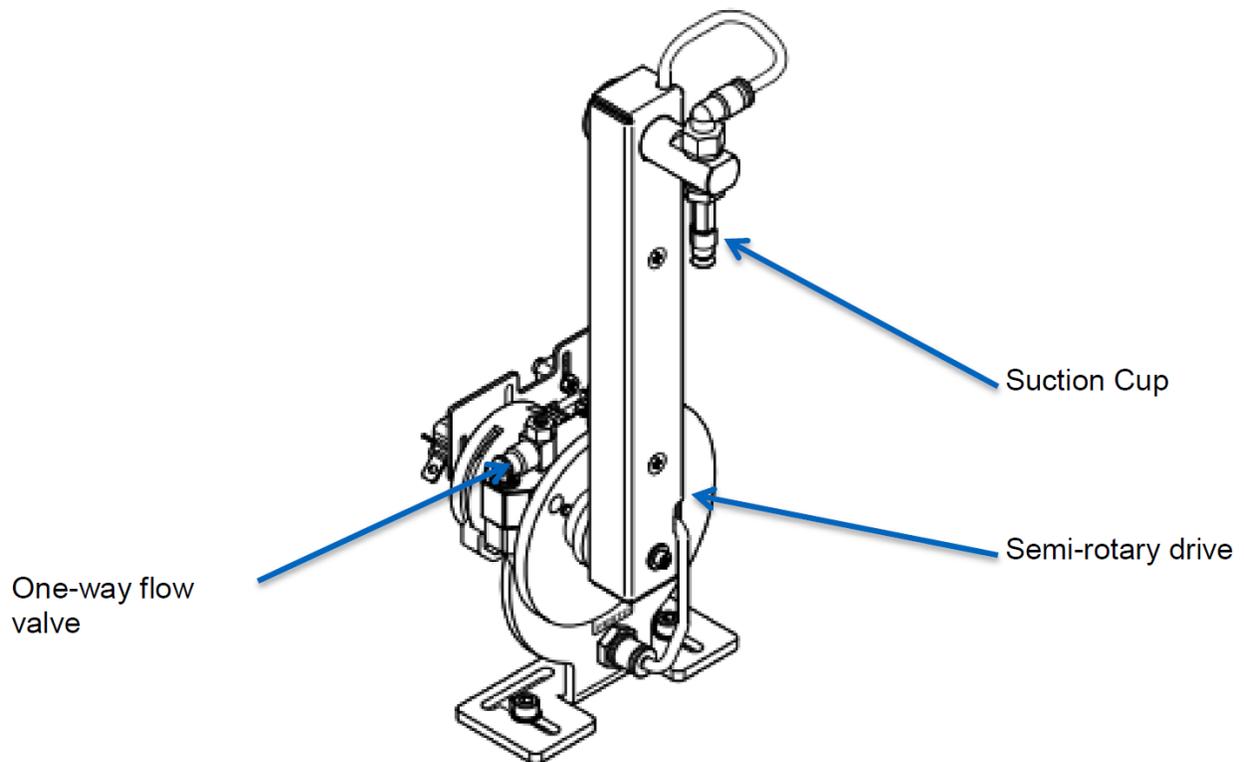


Figure 6 Rotary drive module

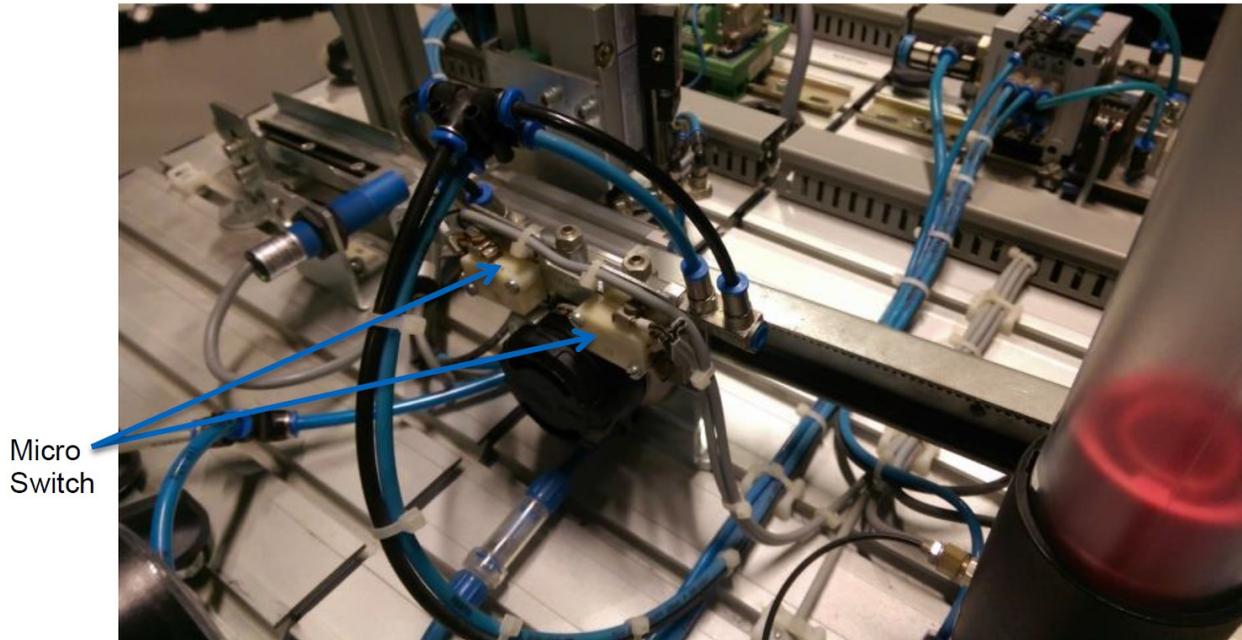


Figure 7 Back side of rotary drive module, showing the micro-switches

No	Part Name	Function
1	Micro Switch	End position sensing of the semi-rotary drive.
2	Semi-Rotary Drive	Pneumatic actuator, double acting, can move between 90° and 270°, with flow control valves to adjust the actuator speed

2.4 Control panel module

The Control Panel module consists of 7 push buttons with indicator light for the operator to control (e.g.start, stop, reset) the distribution station. The indicator light provides the operator status about the station/controller program: for example, a fault or the workpiece magazine is empty. It also includes an Emergency button and a safety relay that allows the operator to shut down the actions of the station during emergency.



Figure 8 Control panel

No	Part Name	Function
1	Push Buttons with LED lights	Generates an input signal when pressed and an output signal may light the indicator light.
2	Emergency Button and Safety Relay	Push down and pull out flip-flop switch. Shut down the power supply to all actuators when the emergency button is pushed down.

2.5 Pneumatic valves subsystems

Pneumatic actuators and sensors operated on compressed air and the valve system acts as the intermediate between the electrical and the mechanical dimension. It uses the electrical control signal to actuate the solenoid valve, in terms of enabling/disabling the flow of compressed supply air to the actuators/sensors.



Figure 9 Pneumatic valves subsystem

No	Part Name	Function
1	3/2-way Solenoid valve	Connected to the Semi-rotary drive
2	Vacuum Switch	Used to detect the partial vacuum at the vacuum suction cup.
3	5/2-way Solenoid valve	Connected to the pneumatic cylinder in the Stack Magazine module.
4	Vacuum generator	Connected to the Suction cup attached on the head of the semi-rotary drive.

2.6 Automatic operation

The tutorial describes how the system is initialized so that the mechanics are driven to a state that is known to the control system. After the system has been initialized, the automatic operation mode may be started. If there is a workpiece in the magazine, the system will start processing it immediately. The cylinder is extended and when it reaches the extended position, the rotary drive is driven left. After it reaches the extreme left position, the suction is activated. After the vacuum sensor determines that the vacuum is on, the rotary drive will be driven right. After this, 2 activities proceed in parallel:

- The magazine cylinder is retracted until it reaches the retracted position
- We wait for the rotary drive to reach the extreme right position

When both of these activities are complete, the suction is deactivated, and the system waits until the sensor determines that the vacuum is off. After this the system starts to process the next workpiece.

In case there are no workpieces in the barrel, the system stops and waits until the operator adds a workpiece to the barrel and presses the start button.

The automatic operation stops immediately if the stop or emergency stop button is pressed. After this the automatic operation cannot be resumed.

3 Testing Station

3.1 Overview

The testing station is responsible for detecting the color, material and height of workpieces and passing certain kinds of work pieces to the next workstation. The testing station handles the following tasks: acquisition of information (test if workpiece is red, metal or black and measure height), comparing specified characteristics with reference values and resulting decision (reject black workpieces and pass red and metal workpieces). Besides these functions, the testing station has to be able to track the position of workpieces and move them along from the sensing module to the height measurement module using the lift module and ejecting pistons and finally to the next station via the slide module.

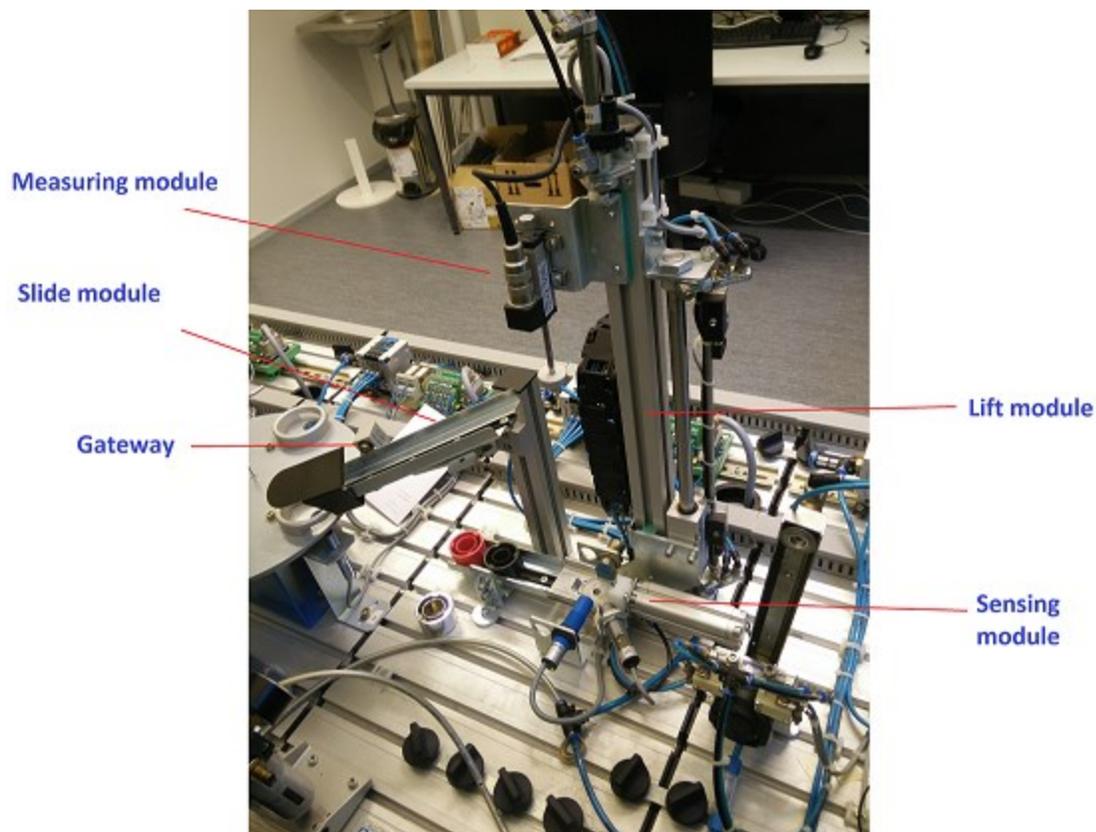


Figure 10 Modules of Testing Station.

3.2 Sensing module

The sensing module consist of 3 different sensor mounted on a lifting module. Besides information acquisition, the sensing module serves as an entry point for workpieces from the distribution station. Workpieces are placed in the middle of all 3 sensors by a rotary drive, which is part of distribution station. Sensors included are a capacitive sensor, optical sensor and inductive sensor. The capacitive sensor senses all types of workpieces and thus serves as availability check. This sensor is also the only one that can sense the black workpiece and thus it is used with combination of other sensors to detect that a workpiece is black. The inductive sensor detects only metal pieces and the optical sensor is used to distinguish between

red and black pieces. Black pieces are rejected and pushed away from the assembly line with the help of an ejecting piston in the lifting module and a slide.

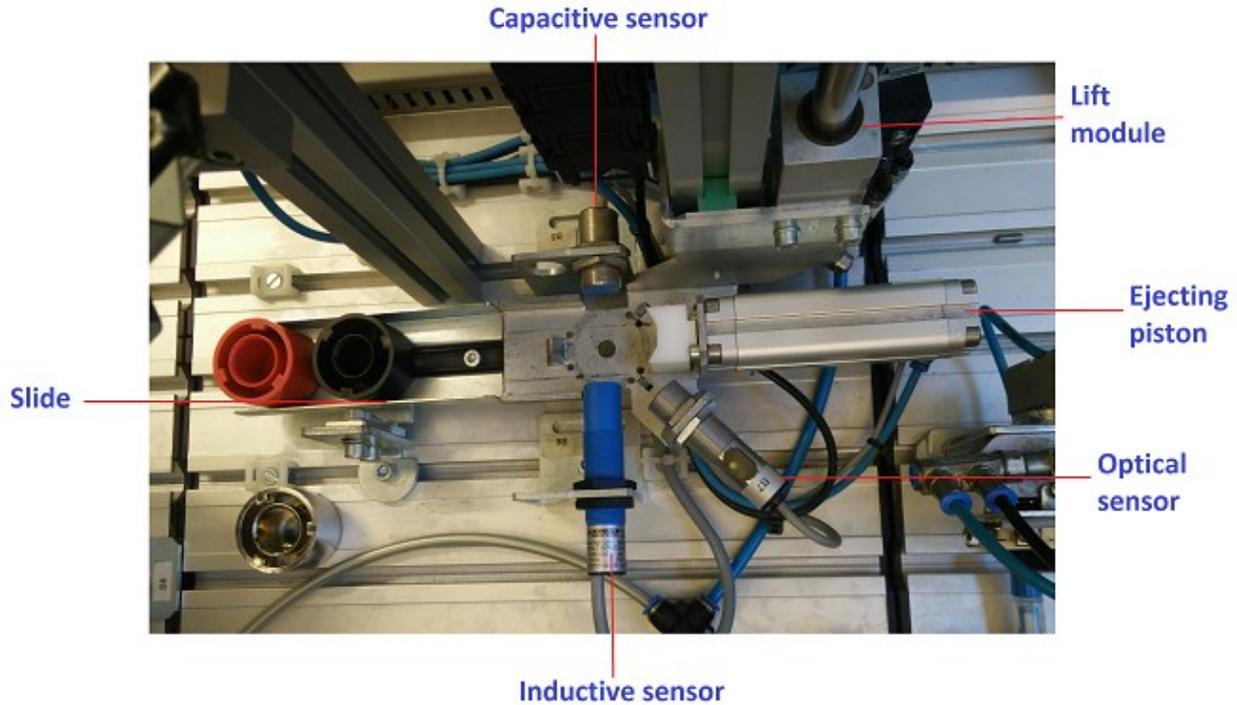


Figure 11 Sensors of sensing module. Ejecting piston of lift module is also visible as well as slide leading outside of the assembly line.

No	Part Name	Function
1	Inductive Sensor	Senses metal workpieces.
2	Capacitive Sensor	This sensor can serves as proximity sensor and can sense all the workpieces
3	Optical Sensor	Sensor senses light colored pieces, which are red and black in this case.

3.3 Lifting module

The lifting module lifts pieces from the sensing module to the measuring module. The elevated position also enables workpieces to slide down to the next station using the slide module of Figure 10 (which is different from the slide in Figure 11). The lifting module includes a rodless lifting cylinder and an ejecting cylinder. There is an inductive sensor at the top position and bottom position of the lifting module. These enable monitoring the two end positions of the rodless lifting cylinder.

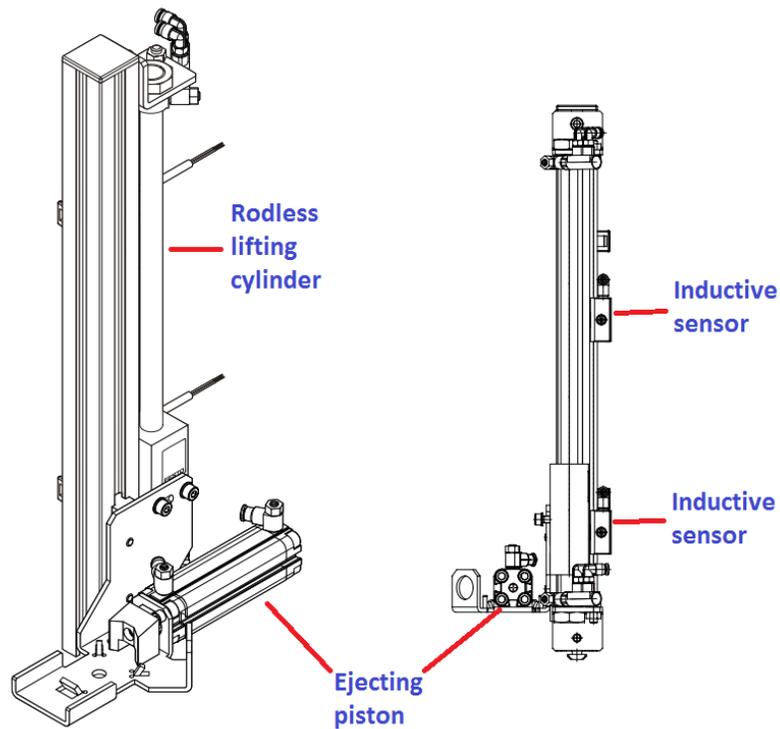


Figure 12 Lift module

No	Part Name	Function
1	Inductive Sensors	Senses if lift module is in top or bottom position.
2	Rodless lifting cylinder	Lifts workpiece with ejecting piston from bottom position to top position and returns empty platform back to bottom position. Pneumatic.
3	Ejecting cylinder	Moves the ejecting piston and thus ejects workpieces to next station (if the lift is in the top position) or out of the assembly line (if the lift is in the bottom position). Pneumatic.
4	Proximity sensor	Detects retracted position of the ejecting cylinder. There is no sensor to detect the extended position.

3.4 Measuring module

The measuring module consists of an analog height measuring sensor, a lowering cylinder that moves the analog height sensor until it touches the top of the workpiece, and an inductive sensor that tells if the measuring sensor is lowered into measuring position. This test is done only to red and metal pieces, since black workpieces are rejected and pushed out of system already in sensing module. All red and metal pieces are of the same height, so this module serves as a quality check in case the sensing module

erroneously sent up a black workpiece. When the measurement is done, workpieces are pushed to the slide module of Figure 10 (which is different from the slide in Figure 11).

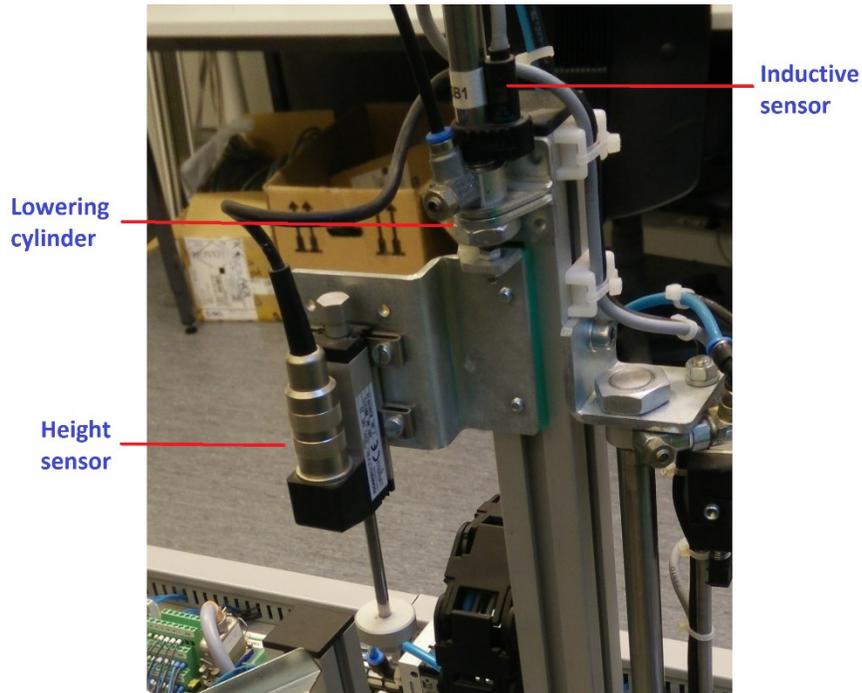


Figure 13 Measuring module

No	Part Name	Function
1	Height sensor	Analog height sensor measures height of workpieces
2	Lowering cylinder	Moves the analog height sensor until it touches the top of the workpiece. Pneumatic.
3	Inductive sensor	Digital sensor that senses the lower position of lowering cylinder

3.4 Slide module

The slide module consist of a sloped sled and gateway. The gateway (see Figure 10) is just a small pneumatic piston that blocks workpieces from sliding down. When the gate is open, workpieces can slide freely to the next station. The slide can also be considered as a buffer as it can store 3 pieces before they are released to the next station.

No	Part Name	Function
1	Sled	Sloped sled allows workpieces to slide down to next station. Up to 3 pieces can be stacked on the sled if gateway is closed.
2	Gateway	Pneumatic ejecting cylinder. Blocks way to next station when extended.

3.5 Control panel module

Control panel module of testing station is exactly the same as in distribution station.

3.6 Pneumatic valves subsystems

Pneumatic valves subsystem is similar to one in distribution system. For the purposes of SysML modelling, you can assume that each pneumatically operated device in the tables above is actuated with a 3/2-way Solenoid valve without going into any further detail.

3.7 Behavior

3.7.1 Initialization

The rodless cylinder is used to lower the lift until the proximity sensor detects that the lift has reached the bottom. Then the ejecting cylinder is extended. Since there is no sensor to detect the extended position, we extend for 1s and then start retracting until the proximity sensor detects the retracted position. (HINT: use a “Time event” in the SysML activity diagram to specify the 1s wait.) The initialisation sequence may be interrupted at any time if the emergency stop button is pressed.

3.7.2 Automatic operation

As soon as a workpiece is received from the previous station, it will be within the range of the following sensors: capacitive, inductive and optical, which will simultaneously perform the sensing and send boolean signals to an activity that detects the type of the workpiece (HINT: you can model this activity outside (i.e. below) the swimlanes as it cannot be allocated to any block in the structural hierarchy of the testing station). Depending on the type of workpiece, we proceed as follows:

- In the case of a black workpiece, the ejecting cylinder is extended for 1s and then retracted until the proximity sensor determines that the cylinder is fully retracted. Then we are ready to receive the next workpiece.
- In the case of a red or metal workpiece, the lift is driven up until it reaches the top. Then the sensor in the measurement module takes the analog height measurement (which you can model as one single activity) after which a digital comparator receives this measurement and determines if the height is ok.
 - If the height is not ok, the lift is driven down until it reaches the bottom, after which the workpiece is ejected in the exact same way as black workpieces.
 - If the height is ok, the workpiece is ejected in the same way as a black workpiece, the only difference being that the lift is in the top position so it will go to a different slide (which you can model as the workpiece being sent to the next station using an activity parameter node). After this the lift is lowered until it reaches the bottom. Then we are ready to receive the next workpiece.

The automatic operation stops immediately if the stop or emergency stop button is pressed. After this the automatic operation cannot be resumed.

Appendix A Notes on Safety

- General
 - Only work on the station under the supervision of an instructor
 - Observe the data in the data sheets for the individual components.
- Electrics
 - Electrical connections are to be wired up or disconnected only when power is disconnected
 - Use only low voltages of up to 24V DC
- Pneumatics
 - Do not exceed the permissible pressure of 8 bar 800kPa
 - Do not switch on the air compressor until you have established and secured all tubing connections.
 - Do not disconnect air lines under pressure.
 - Pay care when switching on the compressed air, actuators may move as soon as the compressed air is switched on.
- Mechanics
 - Securely mount all components on the plate

No manual intervention unless the machine is at rest