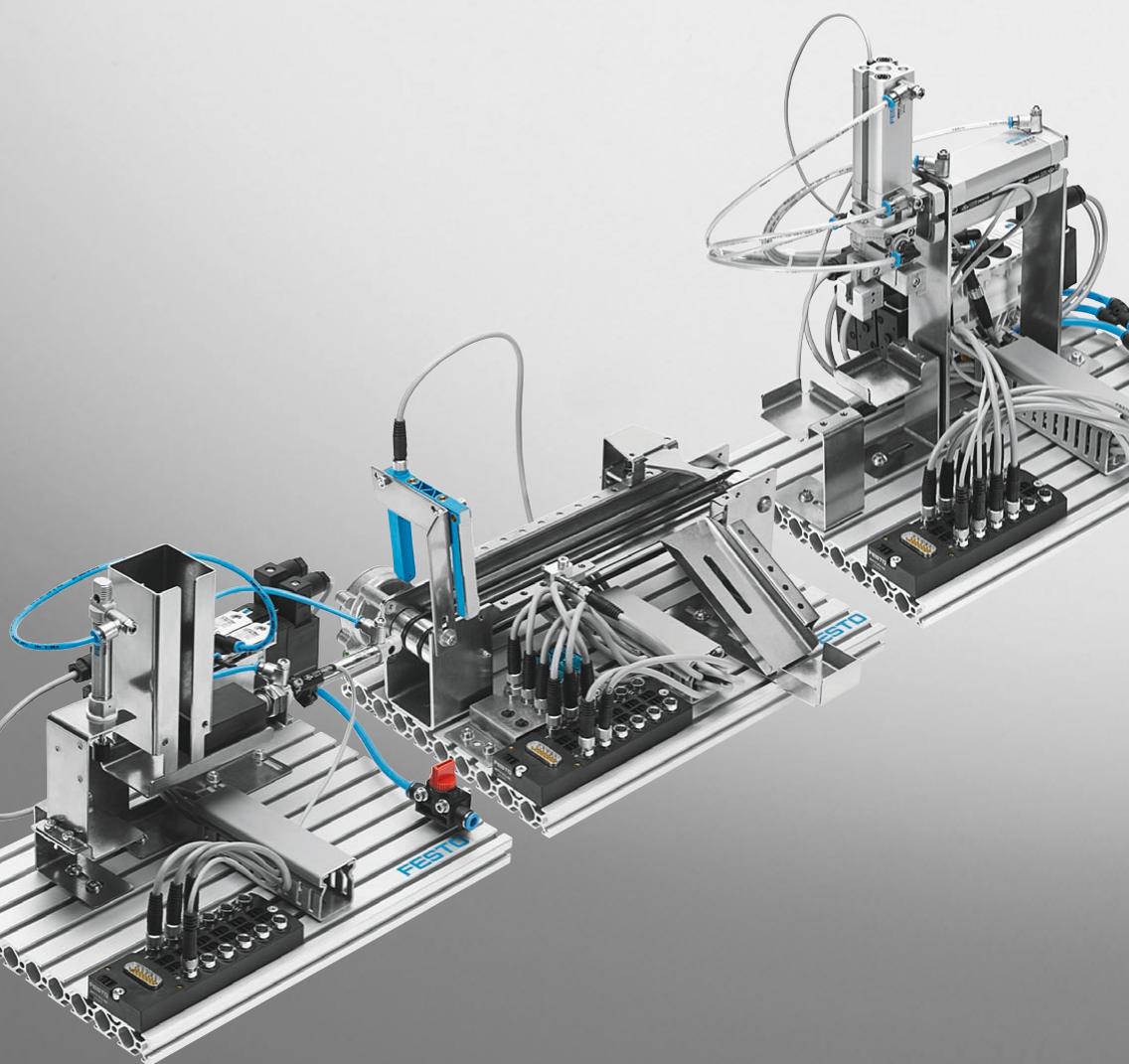


Teaching with MecLab[®]

FESTO

Technology for
secondary schools



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Note

The use of just one gender form (e.g. he, him) in this manual should not be considered gender discrimination; it is intended solely to make the manual easier to read and the formulations easier to understand.

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1 Introduction and didactic background

In the age of knowledge, automation technology is gaining increasing importance as a key division of engineering sciences. As a technical/scientific achievement, it is an expression of creative thoughts and actions of engineers and natural scientists. Automation technology brings about lasting changes to the working and living conditions of people by ensuring high productivity and consistent product quality while at the same time satisfying people's ever-growing need for technological know-how. This applies as much to people's professional as to their private lives.

As a technical area of science, automation technology combines knowledge from virtually all other technical sciences. Such an intensely interdisciplinary field of study could scarcely have developed to the extent it has without scientific fundamentals from electrical engineering, mechanical engineering, process engineering and information technology to name just a few.

People of all age groups come face-to-face with automated technical systems every day. They use escalators, wait for automatic doors to open, see their groceries move along conveyors at the supermarket and operate automated teller machines. Automation technology, in this sense, is everywhere. Everyone, in every aspect of their lives, is regularly confronted, either directly or indirectly, with the purposeful selection and use as well as the evaluation and assessment of automated systems.

The objectives of future-oriented, general technical education must therefore be more strongly geared towards this technology than in the past.

Specific objectives are:

- promoting implicit and explicit knowledge of automated systems,
- developing skills and abilities in the use of automated systems,
- consolidating abilities with regard to appropriate selection, operational commissioning and careful maintenance of automated technical systems.

It is precisely the complexity of automation technology that makes determining the educational content for general pre-vocational technology education difficult yet important. Innovations, essential to every economy, first and foremost require the creativity of technically educated people who have a flexible and above all positive approach to constantly evolving technology. This gives rise to special requirements for general education in technology. It must consist of and provide the content that helps students to understand and deal with technology.

People are expected to adapt quickly to the constantly changing conditions of the professional and working world and to acquire the appropriate competencies. For most people, this is only addressed during vocational training. Basic attitudes, however, are created and acquired much earlier. Consequently, general technical studies as well as technological education as part of work studies or interdisciplinary projects is particularly important. Modern didactics always start from the students' current stage of development and ensure they progress from there.

Pre-vocational technological education is closely connected with other subjects that assist in providing a theoretical grounding for the technology, that reveal and use the links between them and show how they can be applied.

The objectives of pre-vocational technological education can therefore be formulated as follows:

- to convey the essence of technology as a man-made tool that uses and applies laws of nature and exists alongside the forces of nature,
- to promote the understanding of technology as a creative expression of people, inextricably connected with economic, ecological and social wants, needs and must,
- to encourage students to learn about and apply technology,
- to create conditions conducive for creative thinking and action when dealing with technology,
- to assist the individual development of young people, geared towards maturity in general and technological maturity in particular,
- to open up access to integrated action (autonomous planning, execution, monitoring, evaluation) when researching, creating (designing, producing, applying) and learning about technology.

Pre-vocational technological education is based on the latest insights into the psychology of learning:

- Initiating networked, integrated and creative thinking.
- Reflecting on the connections between learning and working as a prerequisite for learning about and advancing technology.
- Developing students' creativity relating to the multi-faceted use of technology in their economic, ecological and social frame of reference.

Criteria for the content of pre-vocational technology studies:

- It should be geared as much as possible towards the world in which students live. The trends in the profound changes brought about by technology in all areas of society as well as in people's private lives must be demonstrated.
- It must be designed so that students have the opportunity to work with technology, investigate its effects and functions and discover their own capabilities in dealing with technology.

Automation technology is one of the most challenging academically since it forms a very complex subject matter within the technology curriculum of a general school system. It can't be taught and learned solely through lectures by a teacher and multimedia lesson units. Involving experts in class work or going on factory tours as a "bridge to practice" is also insufficient.

Instead, students must be offered the opportunity to get hands-on practice with automated technical systems, to observe and understand how subsystems and components interact and to be able to assemble and disassemble them. It's all about learning through experience with all the senses. Complex models can be used in the lesson to this end as enactive, i.e. realistic, media. They convey information, represent reality, are communication tools and enable active autonomous and co-operative learning. Models bring every day practice into the classroom.

The MecLab[®] teaching and learning system developed by Festo Didactic, with its stacking magazine, conveyor and handling subsystems, simulates automation practice; its aim is to familiarise students with automated technical systems. Its focus on learning objectives means it can be called a learning media system. Its three subsystems (stacking magazine, conveyor, handling) are separate but can also be used in combination and can thus be seen as an example of learning media complexes. They combine reproductive learning about a disassembly object with productive learning about a production object.

The modules can be used to design models, where the focus is on synthesis. Models that can be dismantled and adapted to different requirements by the students through conversion and modification, as is the case in the MecLab[®] system, can be used for both analysing the component parts of a technical system and re-integrating those parts and trace them back to a coherent unit.

MecLab® is a modular multimedia teaching and learning system. It is supplemented by

- computer software,
- video clips,
- technical drawings,
- diagrams for the flow of matter, energy and information.

Linking of theory and practice is an essential aspect of MecLab® and its components. Students learn about the practical applications of theories and learn their value as individual statements and statement systems, hypotheses, theses, premises, principles, rules and laws, and therefore will be able to appreciate why they are important. For every theory related to engineering sciences, there is a corresponding application. Generally speaking, practice is the application of technology.

Links between theory and practice can, on the one hand, lead students to practise what they have learned by studying the theory and, on the other, to analyse practical applications to prove the theoretical fundamentals on which they are based. These links can be methodically constructed in a number of ways. What's important is that students don't learn about practice just through descriptions or pictures, but internalise and experience it as genuine practice or its equivalent and in so doing exercise their problem-solving skills.

Both practical and theoretical aspects of automation technology can be addressed with MecLab®, for example:

- types of control systems,
- fundamentals of sensors,
- functional links between sensors and drives in technical systems,
- basic logic functions,
- elementary fundamentals of programming automated systems,
- economic and ecological consequences of automation of technical processes for society and the individual, etc.

MecLab® is a sophisticated but also very clear technical system that is mainly intended for use in technically-oriented subjects in the final two years of secondary education. Basic knowledge of production engineering, mechanical engineering, electrical engineering and information technology is helpful, but not essential. All the basic knowledge required such as, for example, physical fundamentals of drive and sensor technology, relays or logic operations can be learned with the help of the appropriate theory section as well as the sample exercises. The focus, however, should be less on teaching fundamentals than on applying them.

The ideal learning objectives when working with MecLab® are as follows:

- Students should learn basic knowledge about the automatic control of machines and systems. As part of this, both problems of operation scheduling as well as aspects of production, conveying and storage of products by means of automated systems can be practically and realistically analysed, realised and verified.
- Students gain an insight into the different technical ways and consequences of linking machines and robot systems. They identify connections between complex automation systems and its economic as well as ecological consequences for the individual and society. They are encouraged to apply basic design and operational principles and to express themselves intelligibly and precisely using the correct technical terms and symbols.
- Students are enabled to describe, develop, document and test technical solutions for the automation of processes, both individually and in teams. They see for themselves the interaction between the technical disciplines of mechanics, electrical engineering, electronics and computer engineering and realise the importance of team work.
- The computer becomes a tool for solving technical and economic problems. Students are prompted to critically and objectively evaluate the results achieved as well as make necessary modifications to their technical solutions.

MecLab® is expected to set new standards for teaching technology by enabling students to understand how engineers think. The use of industrial components as well as industry-standard symbols, circuit diagrams and data sheets results in an almost unprecedented level of realism and practical relevance.

2 Overview of the MecLab[®] learning system

The MecLab[®] learning system essentially consists of three stations that simulate the functions

- magazining and separating,
- conveying and
- handling.

These three processes are typical for all automated production.

Figure 2.1 shows an actual production line for manufacturing formed sheet metal parts. The sheet material is conveyed (conveying function) by means of a roller conveyor (3) to the machining stations (1, 2, 7), where it is shaped. The first robot (4) places the sheets from the conveyor into a magazine (5, magazining function), the second robot (6) takes the sheets from the magazine and feeds them to the third machining station (7) (handling and separating functions).

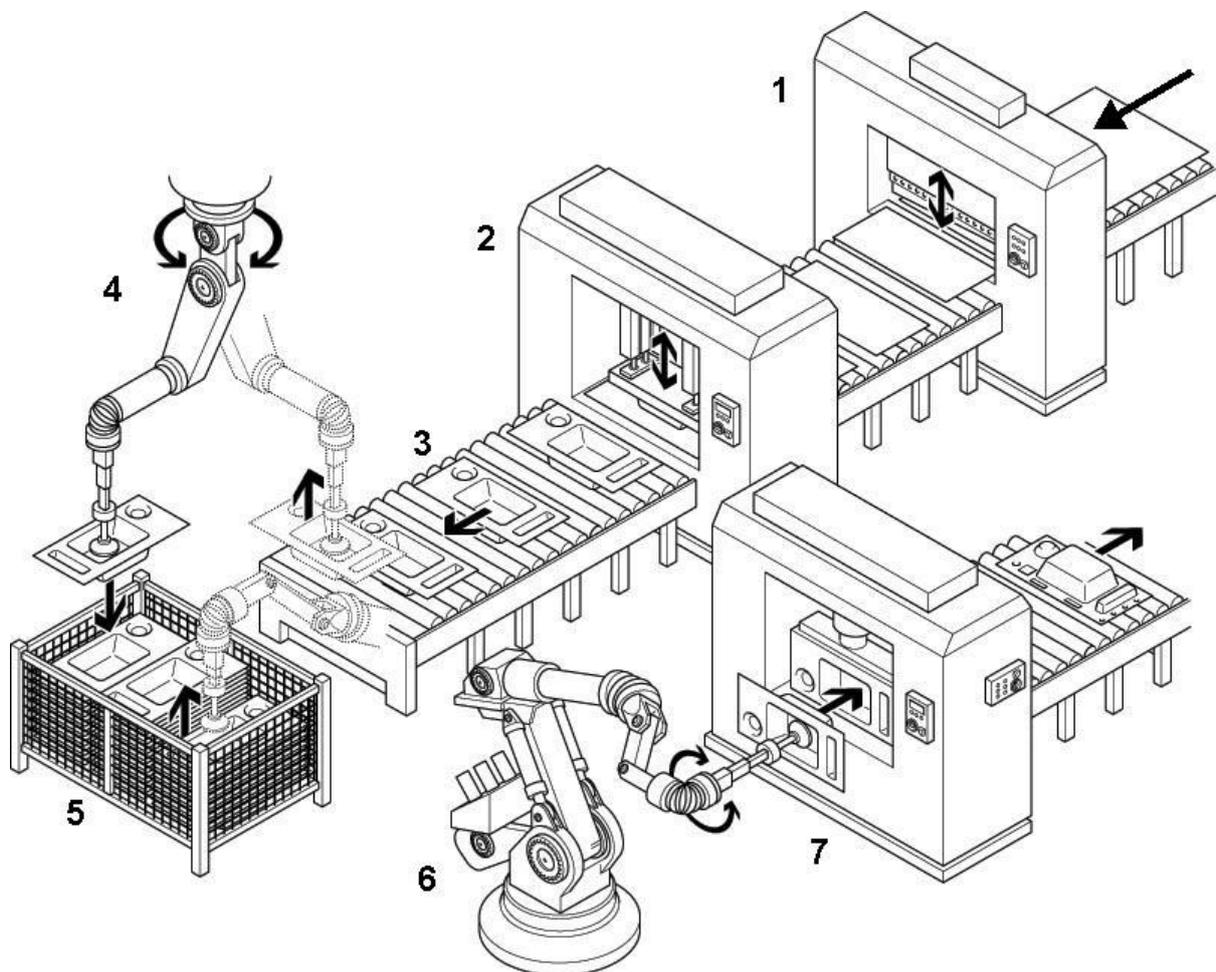


Figure 2.1: Automated manufacture of bent sheet metal parts

The MecLab® stations have similar functions:

- Stacking magazine station
For storing or separating workpieces, the workpieces can be "stamped" in combination with the stamping unit or a simple insertion operation can be performed.
- Conveyor station
For conveying workpieces, which can also be separated or sorted in combination with an ejecting solenoid.
- Handling station
For repositioning workpieces from one station to the next, or the assembly of workpieces.

The functions of the stations can be extended or modified by adding or removing components such as sensors or drives. This is covered in the project exercises.

Example

If the ejecting solenoid is removed from the conveyor station, it can still convey but no longer sort. If it is rotated from one side of the conveyor to the other, the deflector becomes a stopper.

Apart from the stations, the learning system also consists of the following components:

- compressor for supplying the stations with compressed air,
- FluidSIM® simulation and control program,
- EasyPort for connecting the stations to a PC,
- power supply units for supplying power to the EasyPort,
- workpieces,
- tools and small parts,
- didactic instruction material (e.g. this book) on CD-ROM.

The stations are controlled using the FluidSIM® simulation and control program in combination with an EasyPort. The EasyPort allows FluidSIM® to read in sensor signals from the stations and actuate the drives of the stations. The EasyPort is also used to connect the stations with the USB interface of the PC. The EasyPort is supplied with power via the power supply units and the supplied sample programs make getting started with the programming easier.

It is, however, also possible to activate some of the station functions by actuating the valves directly (pressing the blue manual override button on the valve).

The stations are supplied assembled. They can, however, be converted using the tool provided to facilitate other technical functions. All the stations have their own function and can therefore be used on their own. It is possible to swap components between the stations or to join the stations together into a production line.

You will find the following components in the supplied documentation (on CD-ROM):

- Introduction (this document)
- Commissioning instructions for all three stations
Step-by-step instructions on commissioning.
- Theory section
Explains the key technologies, components and backgrounds that can be important for working with MecLab.
- Exercise sheets
These exercise sheets will help your students to familiarise themselves with the MecLab learning system, learn about the main technologies and complete simple projects.
- PowerPoint presentation
Compilation of important graphics for explanation during the lesson.

You can also get information on all MecLab components in FluidSIM® by dragging the mouse over the corresponding symbol and right-clicking.

3 Commissioning the stations

3.1 Installing FluidSIM®

The FluidSIM® simulation and control program is needed to control the Meclab® stations. It must be installed first on a computer which has a CD-ROM drive as well as a USB interface (version 1.1 or higher).

To install FluidSIM®, insert the enclosed CD-ROM, open the FluidSIM® directory, double-click on the "setup.exe" file and follow the installation instructions.

3.2 Assembling the stations

The Meclab® stations are supplied assembled. To commission a station, perform the following steps:

1. Insert the EasyPort interface module (1) in the Sub-D socket on the multi-pin plug distributor (2) provided for this purpose.
2. Connect the power supply unit to the EasyPort (3).
3. Connect the EasyPort to the PC using the USB cable (4) provided.
4. Launch FluidSIM®, click on "Open file" and load a suitable sample program (see table).
5. Start the sample program by clicking on the start arrow in FluidSIM®.

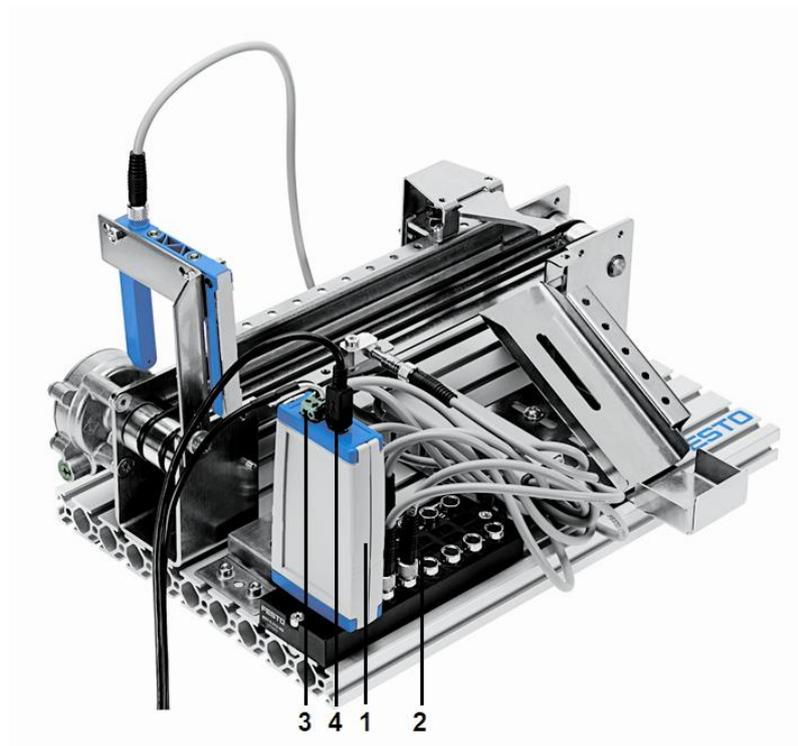


Figure 3.1: Connecting the EasyPort

Overview of sample programs

Sample program	for station	Function
1-4.ct	Stacking magazine	Manually activating single-acting cylinders
1-5.ct	Stacking magazine	Manually activating double-acting cylinders
1-7.ct	Stacking magazine	Pushing out lids and pressing lids onto containers (automatic)
2-5a.ct	Conveyor	Switching on a conveyor by means of a through-beam sensor
2-7.ct	Conveyor	Switching on a conveyor by means of a through-beam sensor, sorting out metal workpieces, switching off after 5 s
2-8.ct	Conveyor	As for 2-7.ct, but with manual reversal of the conveyor direction
DC MOTOR RELAY. ct	Conveyor	Switching the conveyor on/off manually, reversing the direction of rotation
3-4.ct	Handling	Manually advancing the z axis
3-6.ct	Handling	Automatically advancing the z axis, continuous operation
3-7.ct	Handling	Automatically repositioning a workpiece from the rear to the front storage plate

3.3 Safety information

MecLab[®] has been designed in compliance with all the relevant safety guidelines. As with all technical systems, however, there is some safety information that must be observed to rule out any potential hazard to people.



General

- Students must be supervised when working on the stations.
- Note the information in the data sheets for the individual elements, in particular any safety information.

Electrical components

- The power must be disconnected before making or breaking electrical connections.
- Use only extra low voltages (max. 24 V DC).



Pneumatic components

- Do not exceed the permissible pressure of 400 kPa (4 bar).
- Do not switch on the compressed air until all the tubing connections have been established and secured.
- Do not uncouple any tubing under pressure.
- Be especially careful when switching on the compressed air as cylinders can automatically advance or retract.
- Tubing oscillating under the effect of compressed air can cause accidents. Switch off the pressure immediately. Festo Didactic recommends wearing safety goggles. Select the tubing length for the shortest possible connection between two ports.
- Pneumatic circuit assembly:
Connect the devices using plastic tubing with an O.D. of 4 mm or 6 mm. Push the tubing as far as possible into the push-in connector. It does not need to be secured.
- Switch off the compressed air supply before disassembling the circuit.
- Pneumatic circuit disassembly:
Press down on the blue release ring to pull out the tubing.

Compressor

- The pressure can be set on the compressor. This is done by pulling out the rotary knob on the pressure regulator and turning it until the pressure gauge shows the required pressure. The rotary knob is then locked by pressing it back in.
- Do not touch the compressor once it has started running or has been running as it can heat up during operation.
- After switching off the compressor, release the pressure from the compressor tank.
- It is recommended not to leave the compressor running uninterrupted for more than one hour.

Mechanical components

- Install all components securely on the plate.
- Do not place your hand in the station while it is running.

3.4 Maintenance information

MecLab® is essentially maintenance-free.

Condensate must, however, be drained from the compressor tank or water separator at regular intervals. The compressor tank must be inspected regularly for damage.

4 Stacking magazine station

4.1 Technical significance

Temporary storage of raw materials, semi-finished products or finished products is a requisite for all production. This is frequently done on pallets or in (automated) warehouses. In the vicinity of the production line, however, the workpieces need be stored in such a way that they can be fed into the actual production process as effectively as possible.

Many small parts such as screws, nuts or springs are supplied in bulk and have to be arranged before they can be automatically further processed. Vibration feeders (Figure 4.1) are often used for this. The high-speed vibrations move the small parts past so-called chicanes that only let correctly aligned parts through. This means that even though the base material is in a complete jumble, only properly aligned workpieces are fed into the production process.



Figure 4.1: Vibration feeder for storing and sorting screws

Delicate workpieces are generally supplied and stored already sorted. Smaller workpieces are often stored on tapes while larger workpieces are stored on pallets (Figure 4.2 shows integrated circuits (ICs) on a pallet, normally called a tray in the electronics industry).



Figure 4.2: ICs on a pallet

The stacking magazine is one of the simplest ways of storing workpieces in an organised manner. In actual production systems, the components are then supplied already in tube magazines. This means the stacking magazines can be filled quickly.

Apart from the magazining and separating function, the stacking magazine station also offers a "pressing in" function: if a container is placed on the deposit table, a lid can be pushed out from the stacking magazine and then pressed in by the second pneumatic cylinder.

In addition to the electrotechnical content, the stacking magazine station also offers a way of introducing the theme of "pneumatics" into the lesson. Simple exercises on the fundamentals of the function or manual control of a valve can be realised as part of this, as can more complex automated controllers with several pneumatic cylinders using different valves.

The stacking magazine station can be put to flexible use during the lesson. Whether used in the featured lesson or used by the students for individual or team learning, the individual MecLab[®] stations provide a means of bringing the modern professional and working world into the classroom and of explaining its requirements to future "producers".

As with the conveyor and the handling system, the FluidSIM[®] software is used to automatically actuate the stacking magazine. Students get the opportunity to learn about the structure and function of programs for the automation of production sequences. For this they only need the most basic knowledge of dealing with CAD/CAM programs. It is an advantage to have a basic knowledge of:

- the function of simple circuits,
- the operation of common application programs,
- the sequence of production processes and
- the fundamentals of pneumatics.

Students who are completely new to the content or who do not have all of the necessary basic knowledge can learn what they need to know in a reasonable time while working directly on the model as well as its peripheral components and modules.

4.2 Components of the stacking magazine station

The stacking magazine station consists of several individual components that can be used on their own or combined, depending on the task. It has been deliberately designed so it can be flexibly adapted to different technical requirements. All that is needed for this is the enclosed tool.

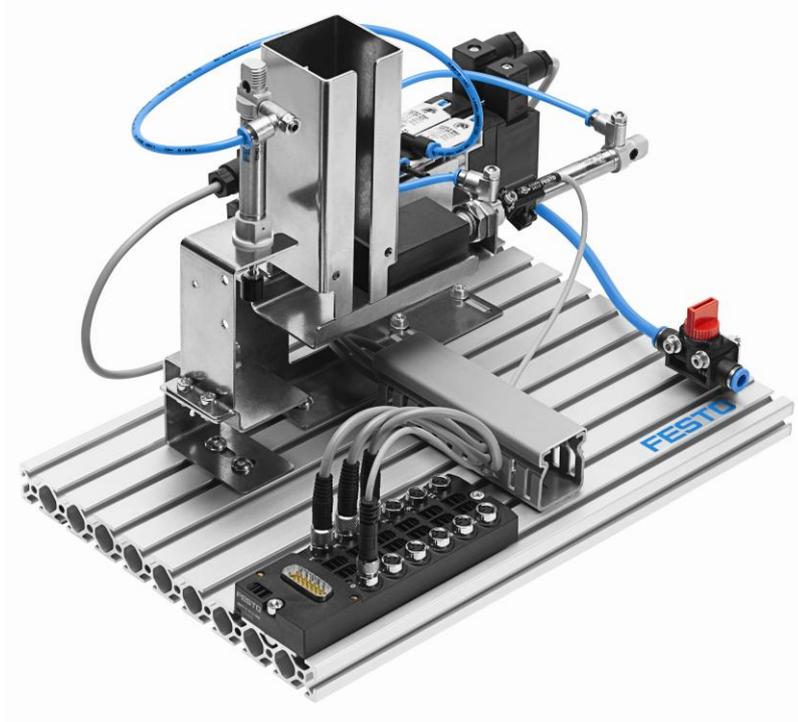
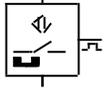
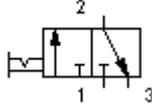
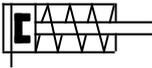
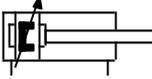
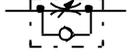
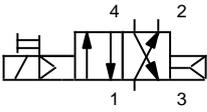
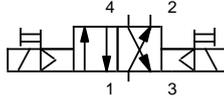
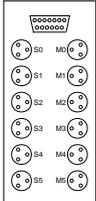


Figure 4.3: Complete structure of the stacking magazine station

The following table lists the most important components of the stacking magazine station together with their circuit symbol.

Illustration	Symbol	Description
		Mounting kit for proximity sensors
		Magnetic proximity sensor for detecting the position of the cylinder piston
		3/2-way stop cock for shutting off the compressed air and exhausting
		T-distributor for distributing the compressed air
		Single-acting cylinder with 50 mm stroke and 10 mm piston diameter
		Double-acting cylinder with 50 mm stroke and 10 mm piston diameter
		One-way flow control valve, used to regulate the speed of pneumatic drives
		4/2-way solenoid valve, with pneumatic spring return
		4/2-way double solenoid valve
		Multi-pin plug distributor for connecting the electrical components

4.3 Assembly and wiring

Meclab® is supplied partially assembled. Nevertheless, for some lesson objectives and lesson methods it may be necessary to disassemble and then reassemble the system. This will not pose any problems if the instructions in this section are followed.

An aluminium profile plate with slots on which the individual components of the stacking magazine are mounted using T-head nuts serves as the base for the station. All the other components are likewise bolted on and can be disassembled and assembled using the supplied spanner and Allen key. The supplied screwdriver is primarily used to adjust the one-way flow control valves. Pneumatic tubing can be cut to the correct length using the tubing cutter.

Note

Do not use scissors or other knives as this can result in leaks.

The stacking magazine station is supplied partially assembled: the single-acting cylinder (the press), the double-acting cylinder (the ejector) as well as the 4/2-way single solenoid valve are assembled, wired and connected. The second double solenoid valve as well as the magnetic proximity sensor still have to be assembled. This is briefly described below.

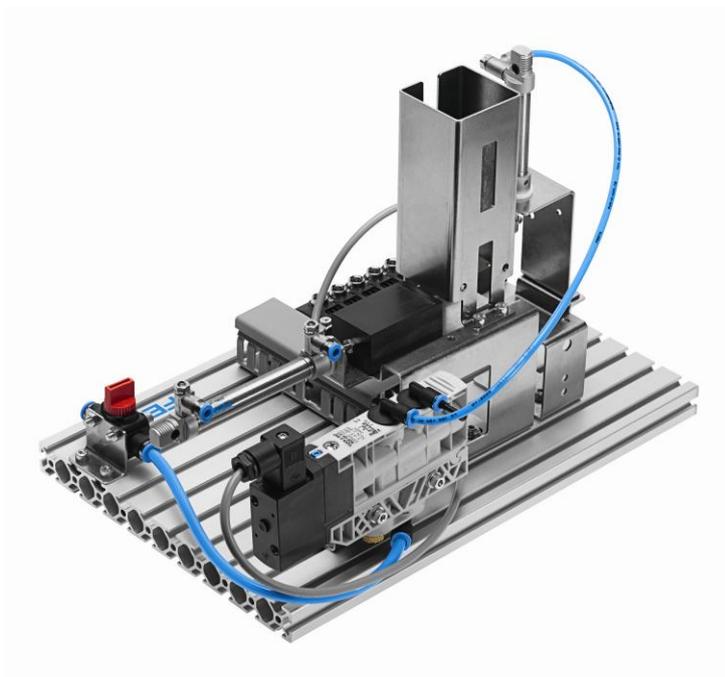


Figure 4.4: Stacking magazine station as supplied

Assembling the 4/2-way double solenoid valve

1. Disconnect the station from the compressed air supply and the power supply.
2. Loosen the retaining screws that connect the already assembled valve to the valve retainer.
3. Exchange the two short screws for the longer ones supplied.
4. Screw down the two valves using the longer screws as shown in Figure 4.5.
5. Install tubing between outputs 2 and 4 of the valve and the corresponding ports on the double-acting cylinder. Port 2 is connected to the front cylinder chamber, port 4 to the rear cylinder chamber. The tubing can be cut to the correct length using the tubing cutter supplied.
6. Connect the valve to the multi-pin plug distributor. Valve solenoid 1M1 is connected to slot 3, valve solenoid 1M2 to slot 5.

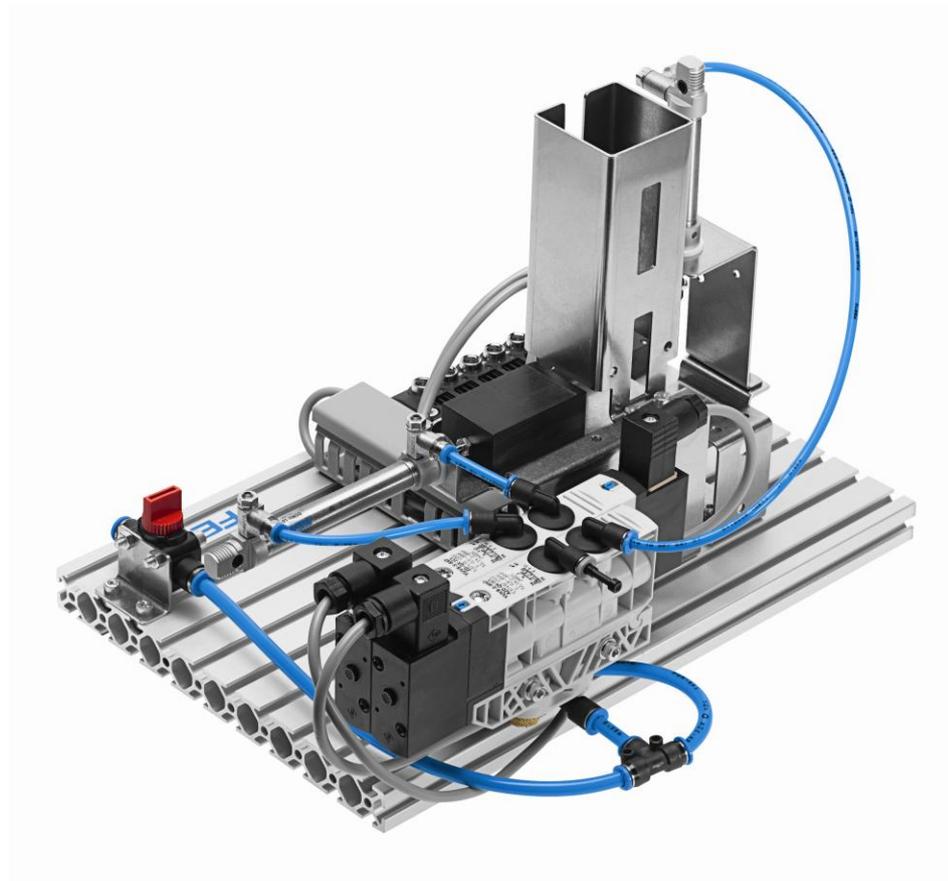


Figure 4.5: Assembling the second valve

It is also possible to install a sensor for checking the end position. This guarantees that the sequence is monitored and enables a further step in the program sequence to be started when the end position of the double-acting cylinder is reached.

The sensor is installed by placing the mounting kit for proximity sensors around the cylinder and securing it using the screw provided. The sensor is then inserted in the retainer and carefully secured by turning the socket head screw half a rotation.

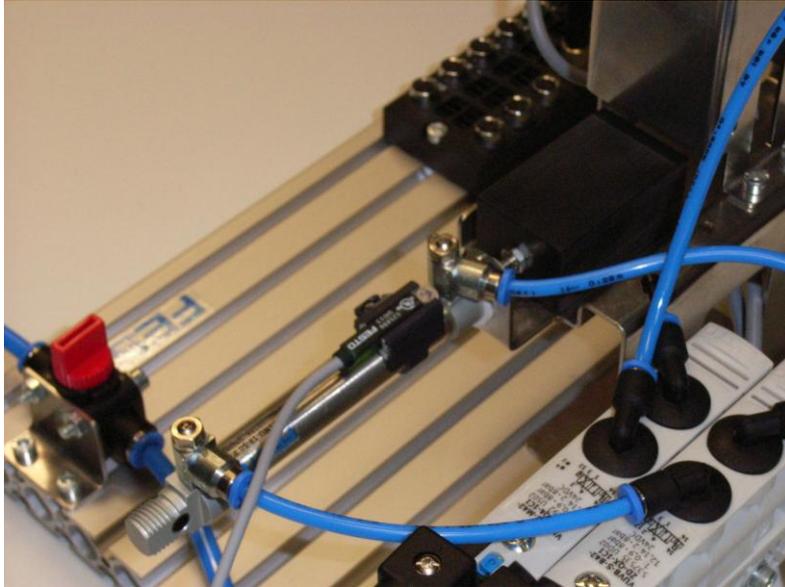


Figure 4.6: Proximity sensor on the cylinder

To be able to establish a connection between the computer and the individual components, the sensors must be connected to the multi-pin plug distributor.

The cables for the valves are connected to the multi-pin plug distributor row labelled with uneven numbers (inputs) (1, 3, 5, 7, 9, 11). The cables for the sensors are connected to the row labelled with even numbers (outputs) (0, 2, 4, 6, 8, 10).

4.4 Converting the 4/2-way solenoid valve

It is easy to change the functionality of the valves used in MecLab®.

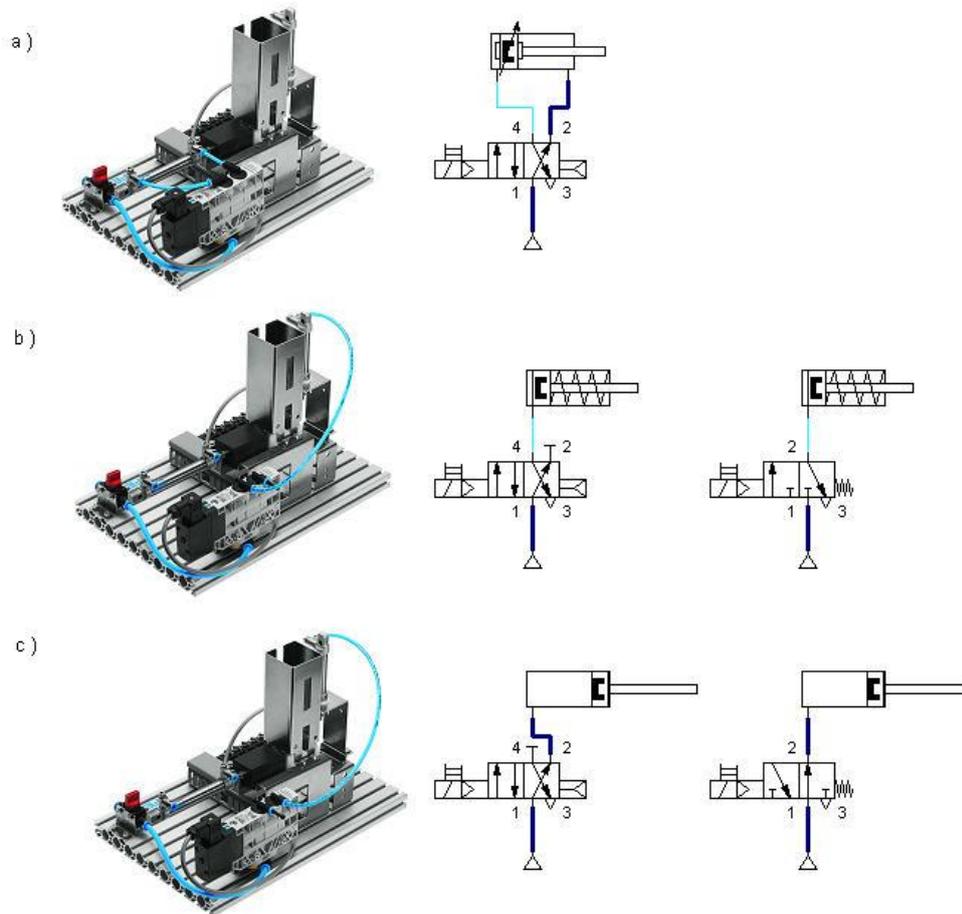


Figure 4.7: Converting a 4/2-way single solenoid valve

- a) 4/2-way solenoid valve (normal use in combination with a double-acting cylinder)
- b) 3/2-way solenoid valve, normally closed (in combination with a single-acting cylinder; port 2 is sealed)
- c) 3/2-way solenoid valve, normally open (in combination with a single-acting cylinder; port 4 is sealed, the cylinder is advanced in the switching position shown)

In their basic function, the valves are 4/2-way valves, i.e. the valve has 4 ports and 2 switching positions.

The station has two valves:

- one 4/2-way single solenoid valve,
- one 4/2-way double solenoid valve.

The 4/2-way valve can be converted into a 3/2-way valve by sealing an output. A normally closed or normally open 3/2-way valve is produced depending on whether output 2 or 4 is sealed.

The 4/2-way single solenoid valve is supplied with output 4 sealed, producing a 3/2-way normally closed valve. This valve can be used to activate the single-acting cylinder (stamping cylinder), for example. Opening output 4 produces a 4/2-way valve for actuating the double-acting cylinder, sealing output 2 produces a 3/2-way normally open valve. If this valve is used to activate the single-acting cylinder, the cylinder will be advanced when the valve is not actuated and retracted when the valve is actuated (cf. Figure 4.7).

4.5 Sample solution to a sample exercise using the stacking magazine

The purpose of this section is to explain the interaction of the FluidSIM® software and the hardware components from the stacking magazine station using a sample exercise.

Task

Develop a stacking magazine that pushes out exactly one workpiece after a pushbutton is briefly pressed and retracts the slide after a second pushbutton is pressed.

Analysis of the task

- The signal to advance must be stored since the pushbutton is to be pressed only briefly.
- The double-acting cylinder is actuated using a 4/2-way solenoid valve.
- The 4/2-way double solenoid valve is used to store the pushbutton signal.

Solution

The second valve as well as the magnetic proximity sensor must first be assembled and connected, if this has not already been done (cf. Section 4.3). The circuit diagram in Figure 4.8 shows an example of how the components can be connected. Table 4.1 describes the connection of the sensor and the valve solenoids to the multi-pin plug distributor.

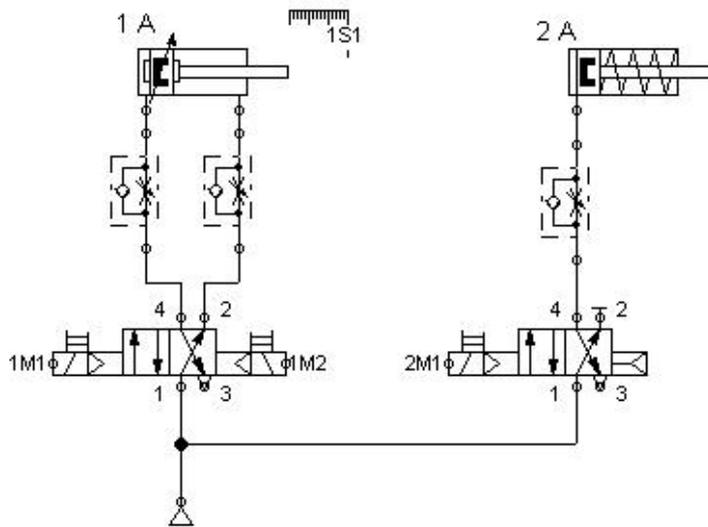


Figure 4.8: Pneumatic circuit diagram of the stacking magazine station

Slot	Assignment	Label
0	Sensor	1S1
1	Valve solenoid	2M1
3	Valve solenoid	1M1
5	Valve solenoid	1M2

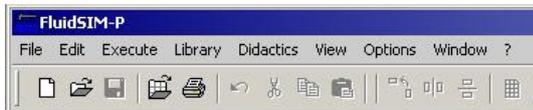
Table 4.1: Pin allocation for the stacking magazine station

Step 1: Launch the FluidSIM® program

- Open the FluidSIM® program by double-clicking on the program icon.



- Call up a new workspace
Click on the blank white page on the left in the second menu bar. A new empty workspace for a controller appears.



- Save the new controller
To do this, select "File > Save As ..." in the menu bar and save the file to the desired location on a data storage medium under a user-defined name.

Step 2: Create the pneumatic circuit diagram

The components needed to create the pneumatic circuit diagram are located in the toolbar on the left side of the screen. They are inserted in the circuit diagram by:

- clicking on the appropriate symbol,
- keeping the left mouse button pressed,
- dragging the symbol to the required location in the circuit diagram and then releasing the mouse button.

The pneumatic system consists of a double-acting cylinder, a 4/2-way double solenoid valve, two one-way flow control valves and the compressed air supply. Figure 4.9 shows the components on the workspace.

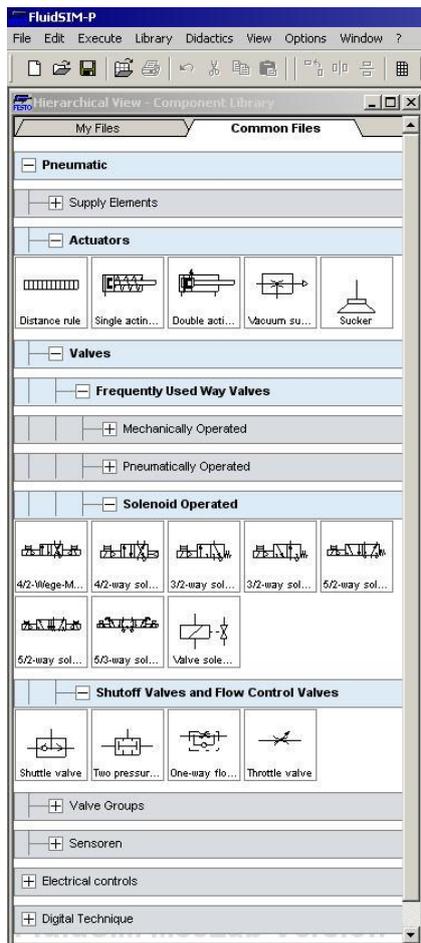


Figure 4.9: Placing the elements on the workspace

The one-way flow control valves should be rotated to produce a clear circuit diagram. To do this, right-click on the symbol for the one-way flow control valve on the workspace; in the context menu that opens, select the menu item "Rotate" followed by "270°".

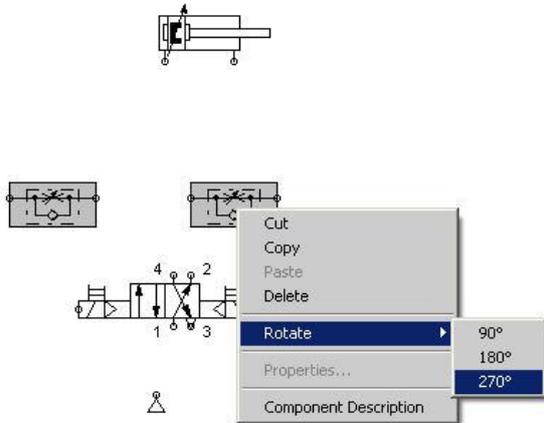


Figure 4.10: Rotating the one-way flow control valves

The components then need to be connected via tubing. To do this, mouse over a node point of the symbol until a crosshair is displayed. With the left mouse button pressed, move to the required node point of the next symbol. Release the left mouse button as soon as the crosshair symbol confirms the connection.

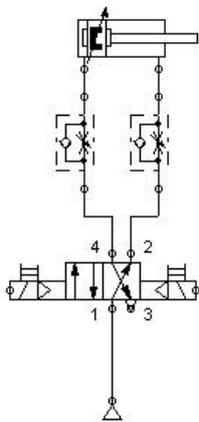


Figure 4.11: Tubing installed between the pneumatic components

To be able to link the valve solenoids with the electrical circuit and the station, the ports of the valve solenoids must be labelled appropriately.

To do this, right-click on the node of a valve solenoid. A context menu opens in which the menu item "Properties" is selected. The designation is entered in the "Label" field. The left-hand valve solenoid is called 1M1 and the right-hand 1M2 as per the connection table.

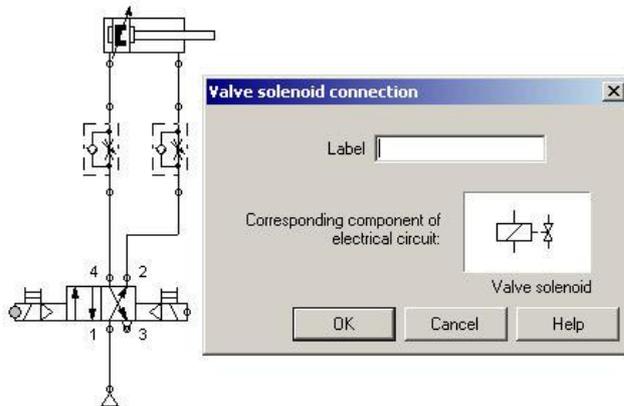


Figure 4.12: Entering a label for the valve solenoid

Step 3: Simulate the pneumatic circuit diagram

FluidSIM® facilitates the simulation and thus the testing of this pneumatic circuit. To this end, the simulation is started by clicking on the Start button.

Left-clicking on the left or right of the respective valve manual override advances or retracts the cylinder.

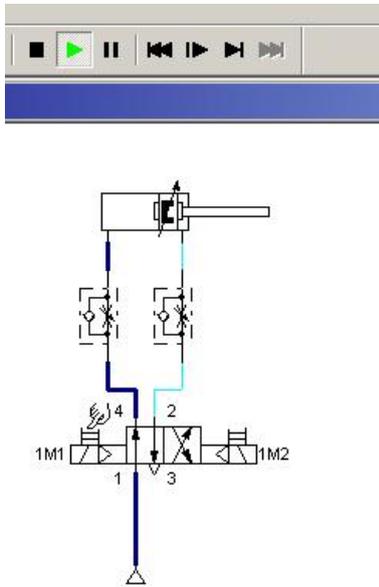


Figure 4.13: Simulating the pneumatic circuit diagram

Step 4: Create the electrical circuit diagram

The components required must first be inserted. To do this, select the symbols in the subcategory Electrical controls in the column on the left. Then drag them to the right side of the program window using the left mouse button.

The following components are required: power supply (24 V and 0 V), 2 pushbuttons (N/O contact) and 2 valve solenoids.

Note

You will find the symbol for the valve solenoid in the subcategory Pneumatic (see Figure 4.9).

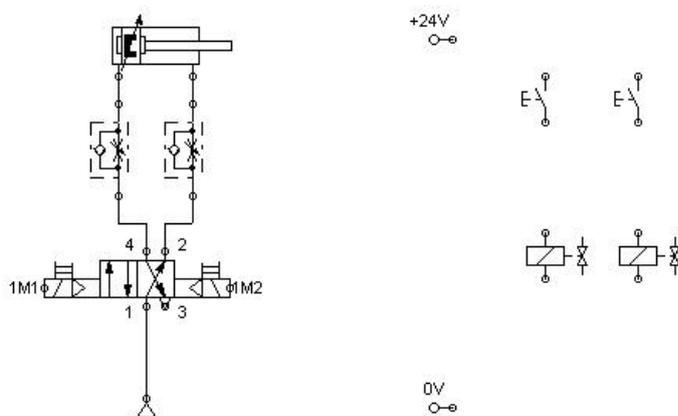


Figure 4.14: Workspace with pneumatic circuit diagram and electrical components

The components are wired in the same way as the pneumatic components by clicking on the contacts and dragging the connecting cable to the next contact.

This produces a circuit diagram like that shown in Figure 4.15.

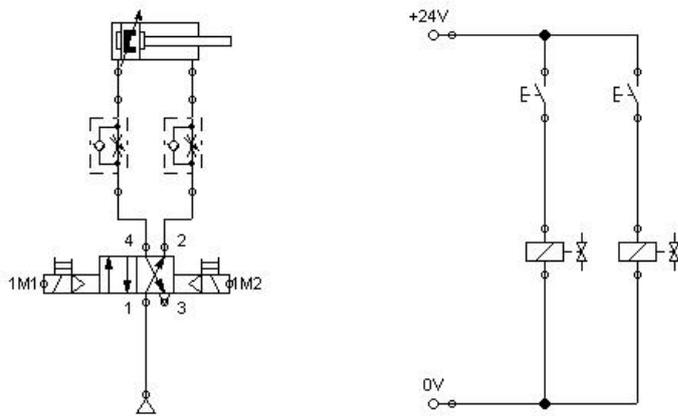


Figure 4.15: Wiring of the electrical circuit

An important step is setting labels for the valve solenoids to guarantee the link between the electrical and pneumatic circuits.

This is done in the same way as for the pneumatic components (cf. Step 3). Right-click on the symbol for the valve solenoid to open the context menu. Select the menu item "Properties". Enter the label in the dialog box (Figure 4.16). The valve solenoids must have the same labels as the ports in the pneumatic circuit diagram, i.e. 1M1 and 1M2 in this case.

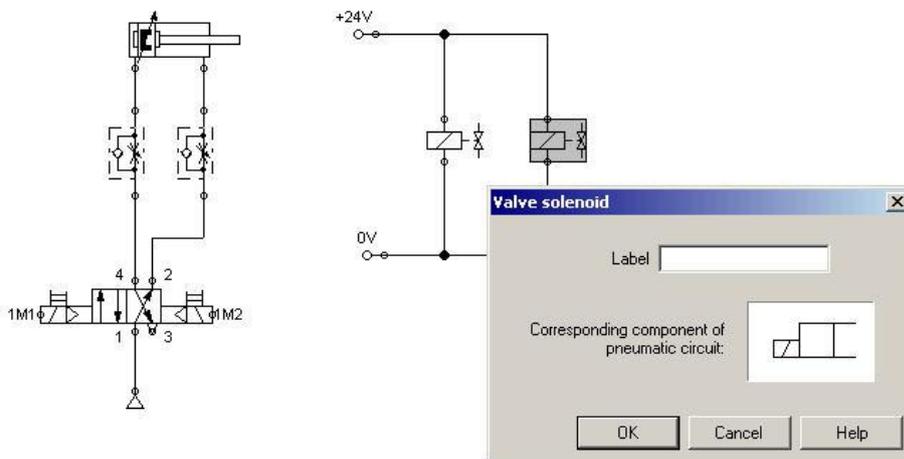


Figure 4.16: Inserting labels for the valve solenoids

Step 5: Simulate the entire circuit

Pressing the Start button starts the simulation in FluidSIM®. This is an easy and safe way of testing the functions of the electrical and pneumatic circuits.

To execute the individual program steps, the pushbuttons must be actuated in simulation mode by clicking on them with the mouse. Actuating the left pushbutton closes the circuit, the solenoid valve reverses, the valve opens the path for the compressed air and the pneumatic cylinder advances. Actuating the right pushbutton retracts the cylinder piston to its initial position.

The following is shown in FluidSIM®:

- Pneumatic circuit
The lines shown in light blue represent the lines not supplied with compressed air, the line shown in dark blue is the line currently under pressure.
- Electrical circuit
The line shown in red represents the part of the circuit that is currently closed (conducting current).

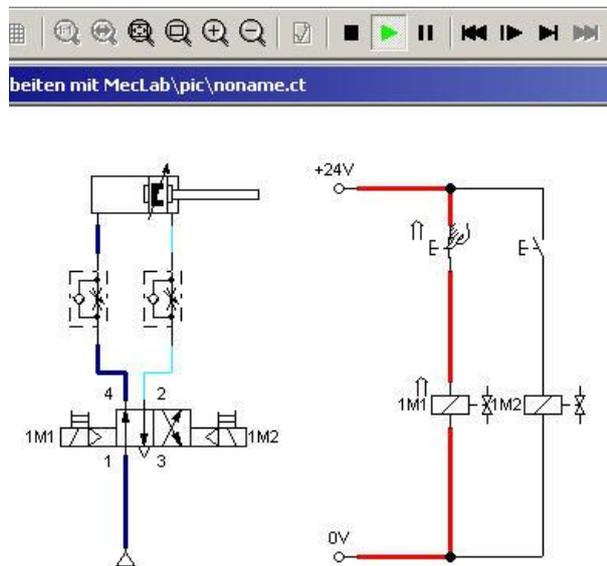


Figure 4.17: Simulating the entire electropneumatic circuit

Step 6: Test with the stacking magazine station**Note**

Please observe the safety regulations when the station is supplied with compressed air and electrical energy.

The actual cylinder will also advance if the symbol for the multi-pin plug distributor is inserted in the FluidSIM® program (provided the station is connected via the EasyPort). An error message will appear if the EasyPort is not connected. Simulation is still possible if this happens (cf. Figure 4.18).

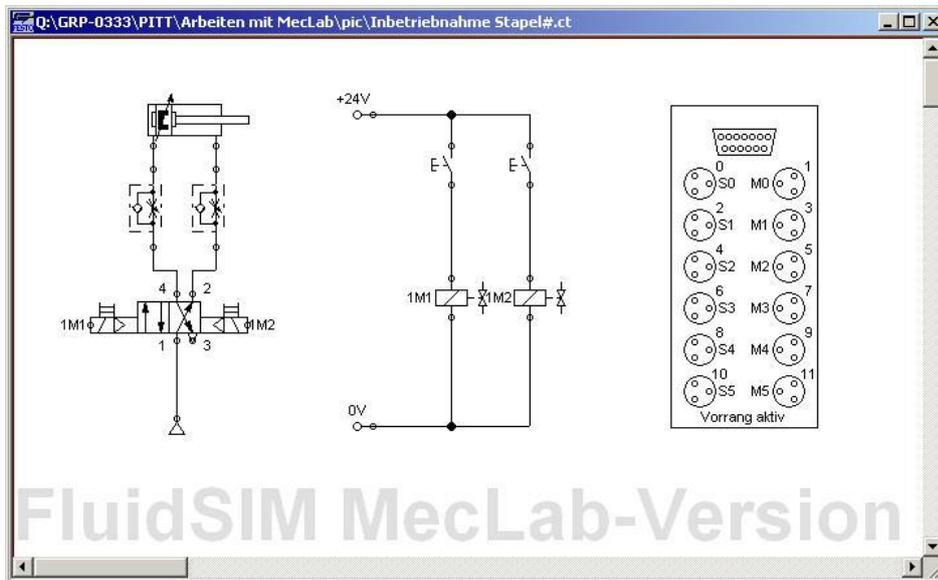


Figure 4.18: Program with multi-pin plug distributor

The labels in the symbol for the multi-pin plug distributor still need to be adapted. To do this, open the symbol by double-clicking on it (Figure 4.19).

Labels are then modified as per Table 4.1. The labels must match those used in the pneumatic and electrical circuit diagrams. The multi-pin plug symbol then establishes the connection to the stacking magazine station. In this case, it makes no difference what the labels are called (1M1 is the usual designation in engineering; the label could also be called "left valve solenoid"). The only important thing is that the same labels are used for the same element in the pneumatic and electrical circuit diagrams and that this element is plugged into the correct slot on the multi-pin plug distributor.

Note

The "Priority when hardware connected" box must be ticked. This ensures that the signals for the actual sensors are used and not those simulated in the program.

If the simulation is started and the pushbutton S1 is actuated, the cylinder in the station advances. The status of the input and output channels is indicated in colour in the multi-pin plug symbol. On the multi-pin plug distributor in the stacking magazine station, the status of the input and output channels is indicated by LEDs. The program can now be extended step-by-step to incorporate the other actuators and sensors into the station.

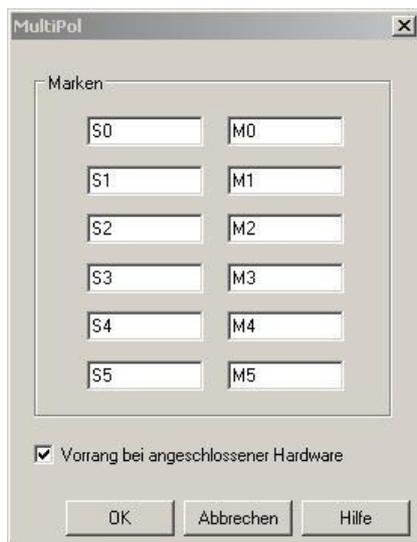


Figure 4.19: Dialog box for the multi-pin plug distributor (default settings)

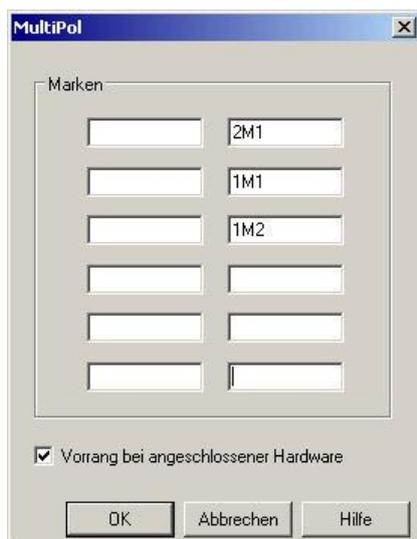


Figure 4.20: Dialog box for the multi-pin plug distributor with labels set

5 Conveyor station

5.1 Technical significance

Conveyors are technical systems that are used in the professional and working world for, among others, the production of material goods in industry, in construction and in agriculture. Conveyors are also hugely important in day-to-day life. Retailers not only use conveyors for merchandise, for example at cash tills in supermarkets, but also in the form of escalators for effortless conveyance of their customers. In stations and airports, they carry passengers through the ever expanding terminals. Their development went hand in hand with industrialisation. In the beginning, animal or human muscle power was used to drive conveyors. Later electric motors were used, and are still used to this day thanks to their many advantages.

The introduction of conveyors revolutionised industrial production. It's impossible in this context not to mention Henry Ford, who, in 1913, pioneered an entirely new method of labour organisation with the development of the assembly line and its use in automobile production. The technology of the assembly line as created by Henry Ford has long since been overhauled to become what it is today. Where at one time manual labour required the continuous presence of workers, these days computer-controlled systems are taking over this role. Digital technology is constantly opening up new perspectives for automation.

Automated systems are being used more and more for sometimes heavy and also monotonous manual labour.

Despite its clearness and transparency, from a technical point of view the conveyor station is a challenging electromechanical lesson medium that can be flexibility adapted to a range of requirements.

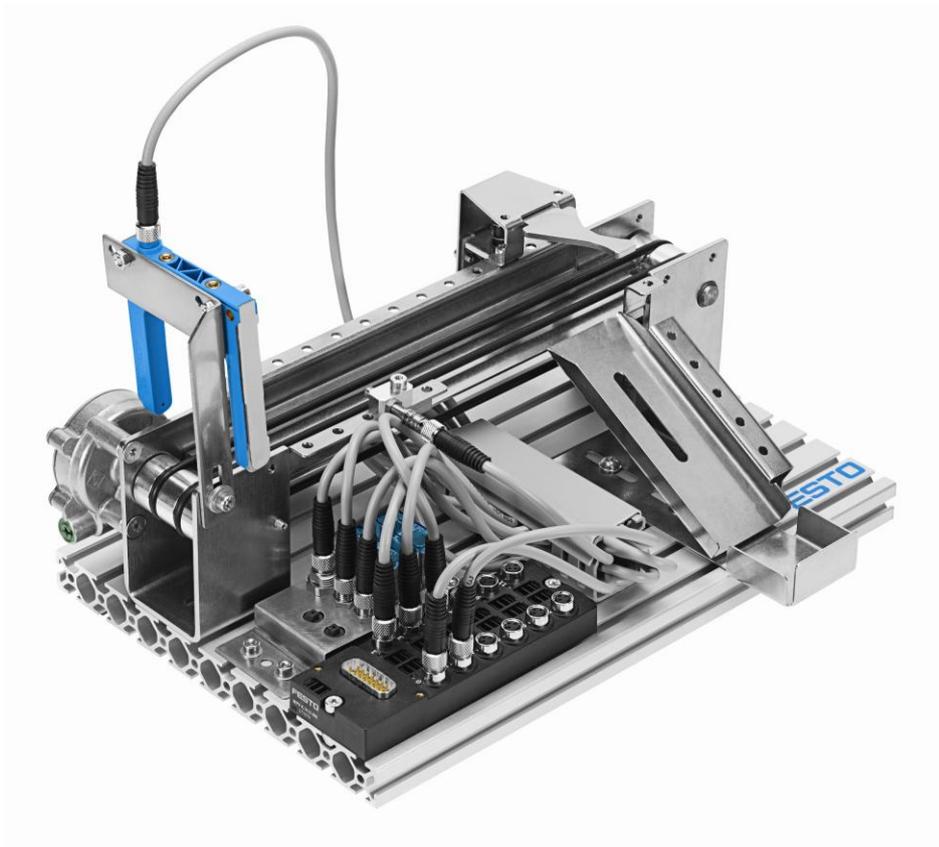
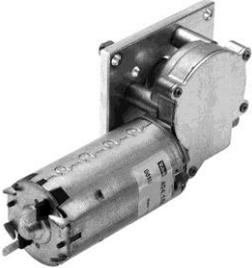
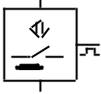
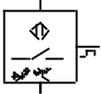
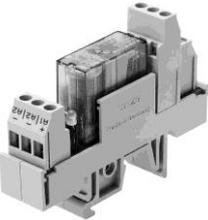
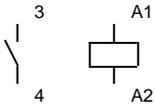
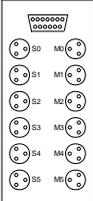


Figure 5.1: Conveyor station

The conveyor station can be viewed both as an integrated as well as a self-contained technical subsystem of the overall model. This means it can be used for different didactic applications. The following discussions assume a self-contained system. As such it consists of modules that can be dismantled further into components. This gives rise to additional opportunities for use within the lesson setting. For example, the conveyor can be used as a complete technical system for a series of lessons or its individual modules or their components can be used for individual lesson topics.

5.2 Components of the conveyor station

The following table lists the most important components of the conveyor station together with their circuit symbol.

Illustration	Symbol	Description
		DC geared motor, moves the belts of the conveyor and all the workpieces lying on them. Can run forwards and backwards.
		Solenoid (stopper/deflector), can act as a deflector or stopper, i.e. eject workpieces from the conveyor or stop workpieces, depending on which side the unit has been attached to the conveyor.
		Inductive sensor, can sense metal or metal-coated workpieces.
		Opto sensor, detects any workpieces blocking the through-beam sensor's beam of light (i.e. all non-transparent workpieces).
		Relay, activates the motor, used to reverse the polarity of the motor (reversal of direction).
		Multi-pin plug distributor, interface for connecting all actuators and sensors of the conveyor station to the control PC.

5.3 Assembly and wiring

The conveyor station is supplied assembled. For commissioning, the station must be connected to the USB port of the PC using the EasyPort as well as to the power supply using the 24V power supply unit as described in Section 3.

The station can be converted in order to fulfil different tasks. The function is primarily determined by the position of the sensors and the solenoid:

- The solenoid can act as a stopper or deflector (which rejects workpieces onto the slide, for example) depending on which side of the conveyor it is mounted.
- The through-beam sensor reacts to all workpieces, while the inductive sensor only reacts to metal workpieces. This enables specific actions to be triggered all the time or only with metal workpieces or only with non-metal workpieces (e.g. starting or stopping the belt motor, triggering the solenoid).

Correct wiring of the actuators and sensors must be ensured if the supplied sample programs are to be used. The correct pin assignment is described in a schematic diagram in the sample program.

5.4 Creating a sample program for the conveyor

The following sample exercise explains step-by-step the mode of operation of the FluidSIM® software as well as its interaction with the "conveyor" hardware component.

Task

The conveyor is to fulfil the following task:

The conveyor should be started by means of a pushbutton and keep running until it is switched off again by means of a second pushbutton or until the workpiece has reached the end of the conveyor. The conveyor motor should then be automatically switched off again.

Analysis of the task

- Only the conveyor motor is required for this task, not the solenoid or the slide. Components that are not required can be removed, but do not necessarily have to be.
- A sensor that detects all workpieces must be mounted at the end of the conveyor. Only a through-beam sensor can be used for this; the inductive sensor can only detect metal workpieces.
- One pushbutton for starting the motor and a second pushbutton for switching it off must be included in the control program.

Solution

The solution involves four steps:

1. Create the mechanical setup
2. Create the circuit diagrams and programming in FluidSIM®
3. Test the program via simulation
4. Test the program with the conveyor station

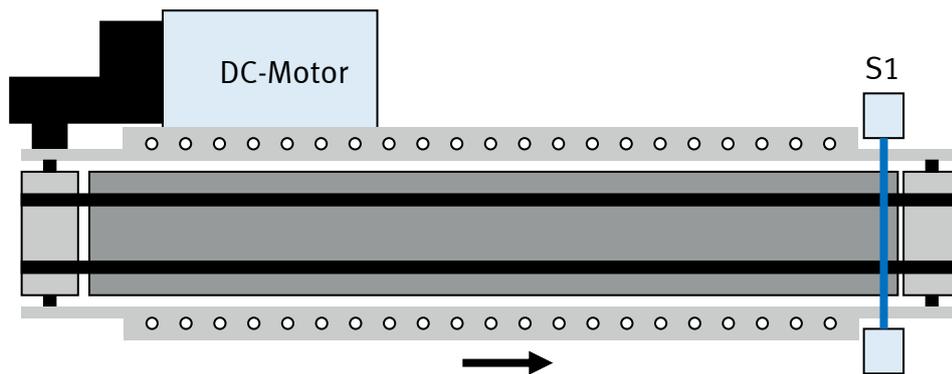
Step 1: Create the mechanical setup

Figure 5.2: Schematic diagram of the conveyor

Figure 5.2 shows a schematic diagram of the conveyor as it is required for the task. This diagram shows the arrangement of the components; it is very important for planning the control program.

The opto sensor (through-beam sensor) must be mounted at the end of the conveyor. This is easily done using the enclosed tool. The stopper can be removed or can remain on the conveyor, as can the slide.

The following table provides an overview of the wiring at the multi-pin plug distributor:

Slot on the multi-pin plug distributor	Assignment
0	Opto sensor S1
1	Motor relay K1

Table 5.1: Pin assignment on the multi-pin plug distributor

Note

Sensors are generally indicated with an "S" in circuit diagrams, relays with a "K".

Step 2: Create the circuit diagrams and programming in FluidSIM®

- Launch FluidSIM®
Double-click with the left mouse button on the FluidSIM® icon to access the start page of the program. Click on "File > New" to open the actual workspace.

- Arrange the required components
All the components required for the simulation are in the so-called component library. This is divided into the following areas:
 - Pneumatics
 - Electrics
 - Digital technology
 - EasyPort
 - Miscellaneous

Only the "Electrics" and "Digital technology" areas are required to control the conveyor. Left-click on the required area to access the respective subareas and the corresponding components. Left-click on the chosen symbol for the component and hold to drag it to the workspace. All the components required to solve the task are selected from the component library and arranged appropriately to their function in the workspace.

The following table provides an overview of the most important components in FluidSIM®.

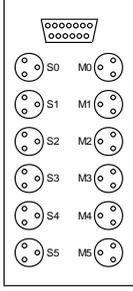
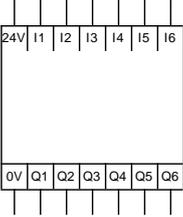
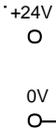
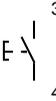
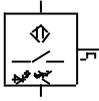
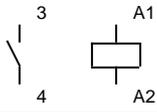
Graphical symbol	Designation	Function
	Multi-pin plug distributor	Establishes the connection with the hardware, the labels must match the corresponding labels for the actuators and sensors in the FluidSIM® program.
	Digital module (this can also be a small programmable logic controller (PLC))	Contains the logic program, is opened by double-clicking on it.
	Voltage supply	Supplies the components with power. Attention: Without power, the components will not work in the simulation.
	DC motor	Drives the conveyor, is switched on and off via relays.
	Switch (manually actuated)	For manual intervention in the program.
	Sensor (opto)	The connections on the top and bottom are for the power supply, the connection on the side is the signal output.
	Relay coil with switch	When current flows through the coil, it switches the associated switch (i.e. the switch with the same label).

Table 5.2: Important components in FluidSIM®

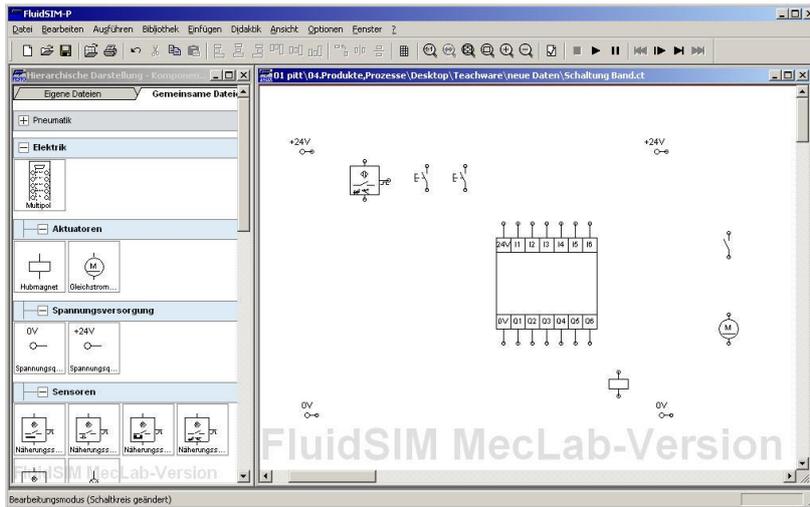


Figure 5.3: Workspace of FluidSIM® with all the required components

– Wire the components

To join two components together, click on the end of the line of one component, keep the left mouse button pressed and drag to the desired connection on the other component. Figure 5.4 shows the fully wired components.

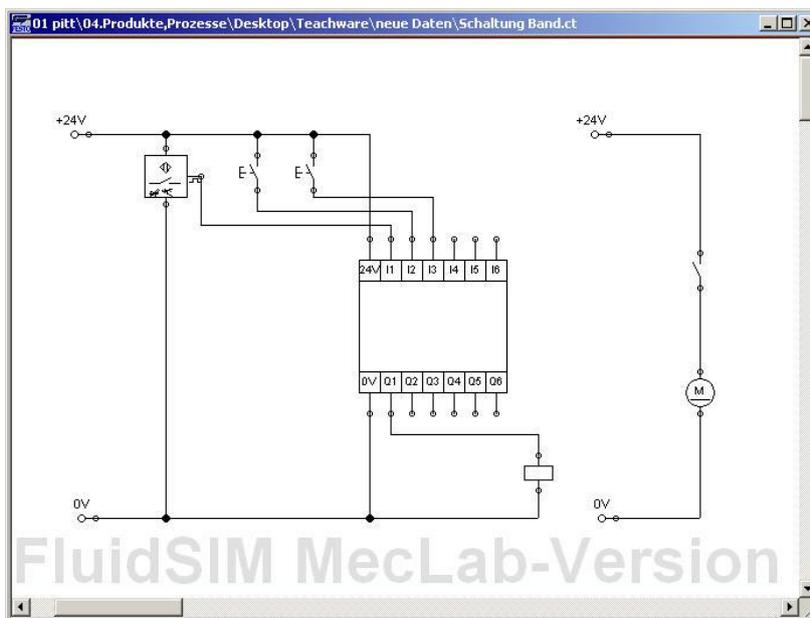


Figure 5.4: Wiring of the components

Note

Incorrect connections can be deleted by simply clicking on them and pressing the "Delete" button.

– Set labels

Labels are set so that FluidSIM® knows which components belong together.

This is done by right-clicking on the symbol for the component. This opens the context menu where you select the menu item "Properties". You enter the label in the dialog box (cf. Figures 5.5 and 5.6).

Both parts of the relay must have the same label, in this case K1. The sensor is also labelled (S1), as are the two pushbuttons (T1 and T2), cf. Figure 5.7.

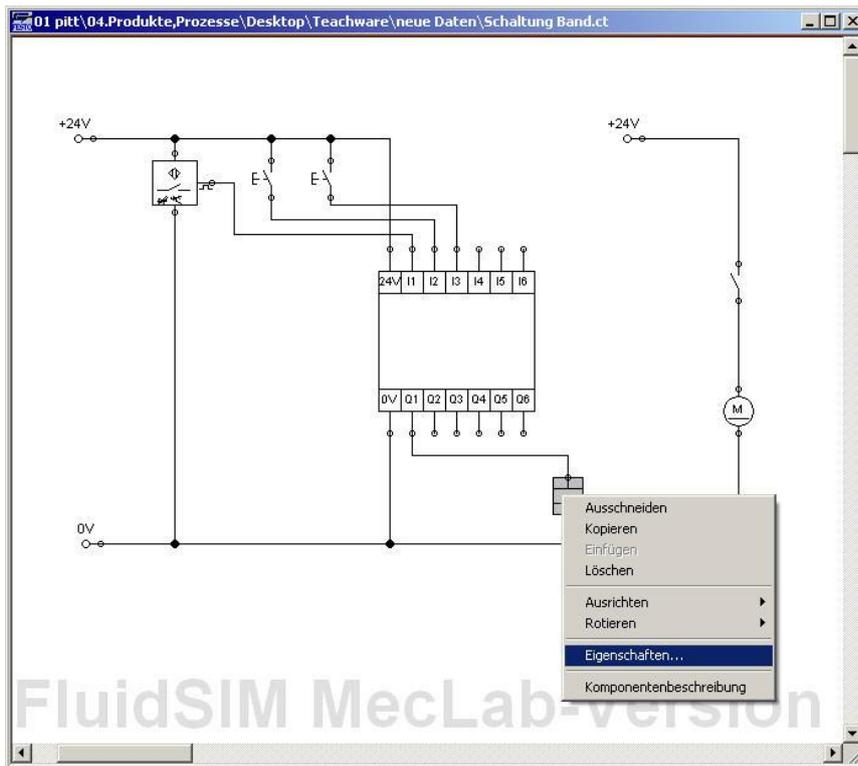


Figure 5.5: Setting labels (1)

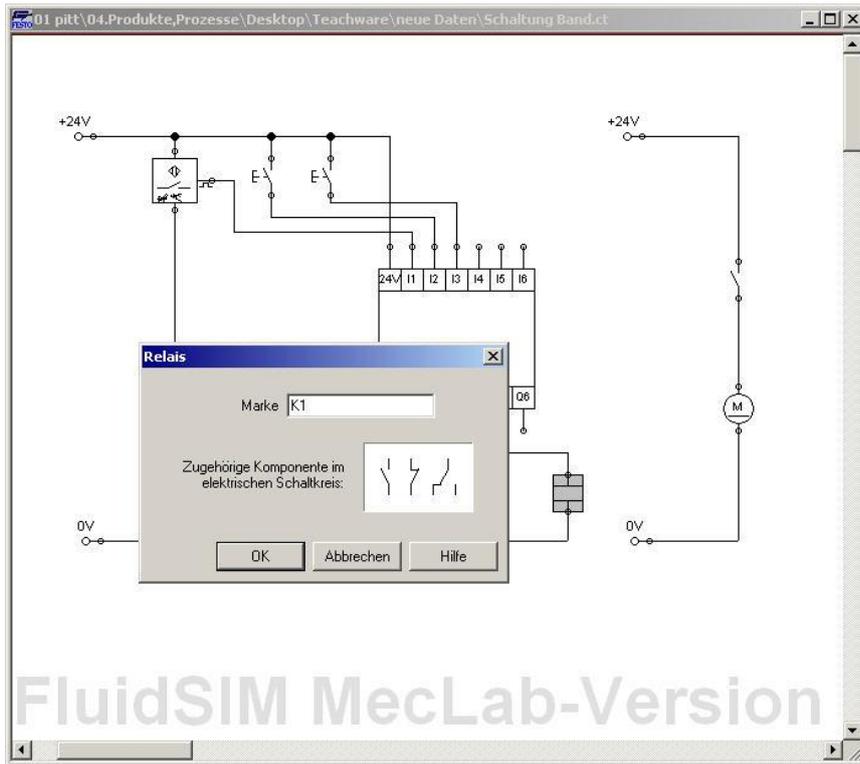


Figure 5.6: Setting labels (2)

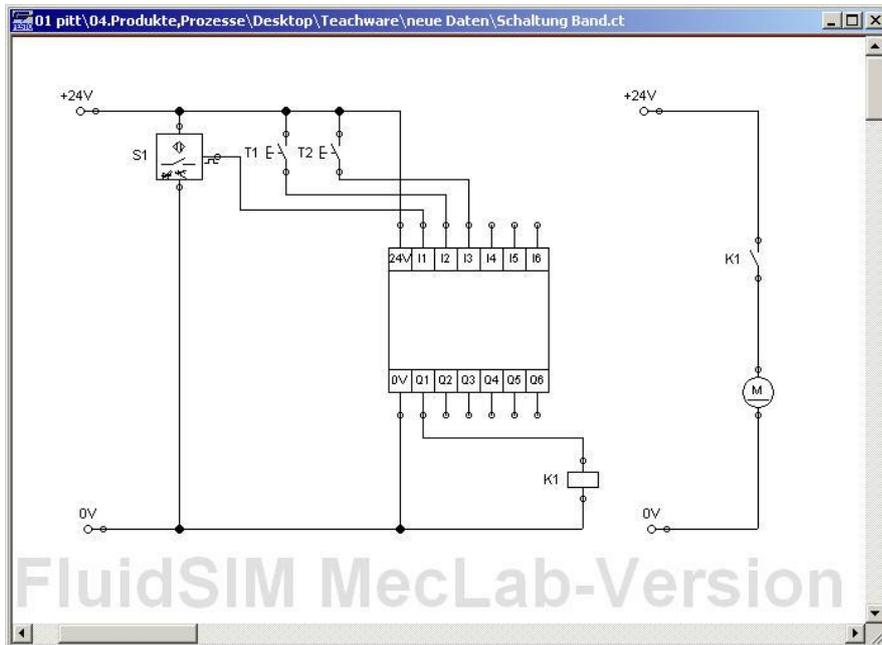


Figure 5.7: Circuit with set labels

- Link the logic modules in the digital module
To be able to enter the logic program in the digital module or the PLC (programmable logic controller), the digital module must be opened by double-clicking on it. A new window containing the digital module's input and output channels is displayed.

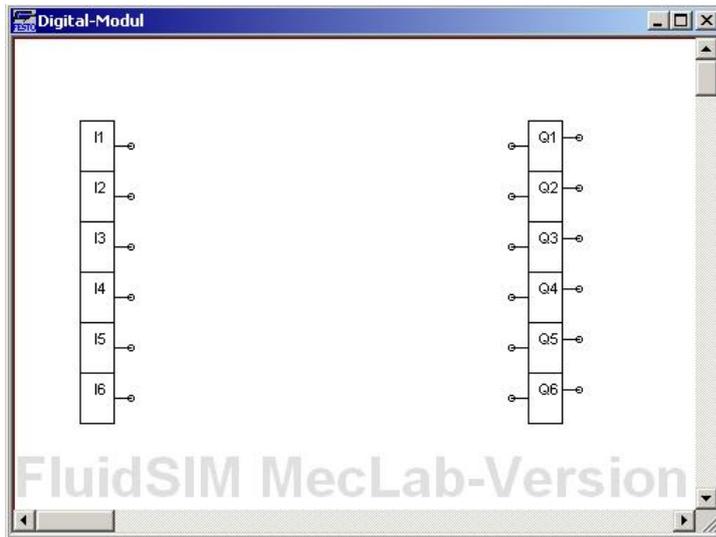


Figure 5.8: Input and outputs channels of the digital module

On the left side are the inputs marked I1 to I6, on the right side the outputs marked Q1 to Q6. You now link the inputs and outputs using logic modules. These are in the toolbar on the left side of the screen and are dragged to the workspace and connected to each other like all other components.

The main purpose of the PLC is to process the signals supplied by the sensors in such a way that the actuators can fulfil the required function. This is done with the help of the logic modules.

The following functions are required:

- The motor is to start when a pushbutton is actuated, i.e. a latching element (RS element) is required to store the pushbutton signal.
- The motor is to stop again when the second pushbutton or the through-beam sensor is actuated. An OR gate is required for this.

Figure 5.9 shows the digital module (or the PLC) with the connected logic gates. Closing the input window stores the program in the digital module (or PLC).

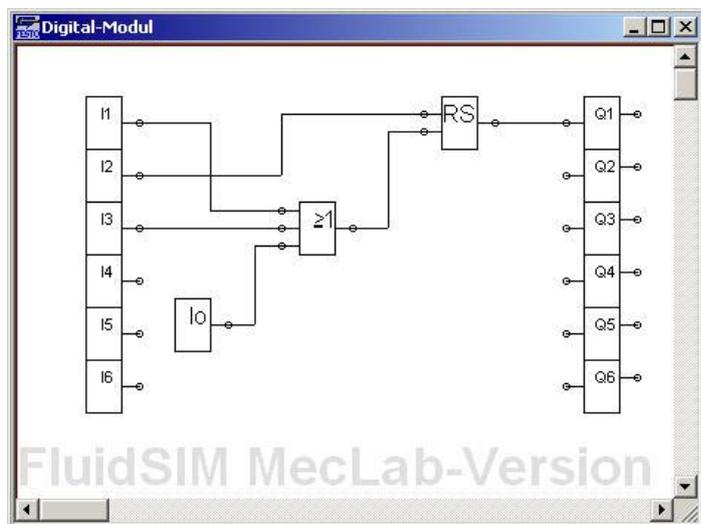


Figure 5.9: Digital module with logic gates

Note

The low module serves to always set the third input of the OR gate to zero. The program will also work without the low module, however using it avoids one source of trouble since the input could otherwise be undefined.

Step 3: Test the solution via simulation

To start the simulation, the window of the digital module must be closed. The program is now ready and can be started by clicking on "Start" or by closing the main switch.

Clicking on the pushbutton T1 starts the motor (indicated by a small arrow). The sensor's response can be simulated by clicking on the sensor S1. The motor stops.

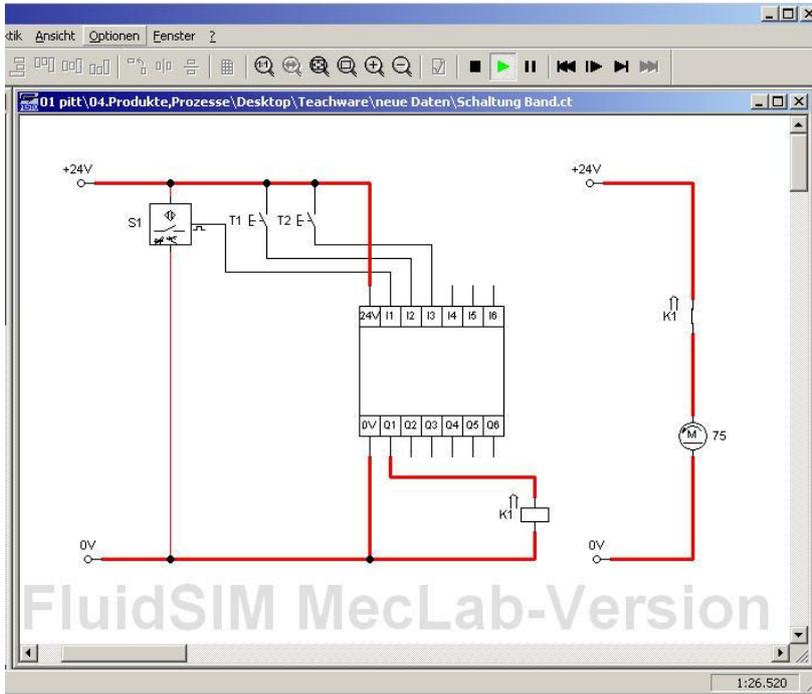


Figure 5.10: Simulation mode, pushbutton T1 actuated

Step 4: Test with the actual conveyor station

To control the station using the FluidSIM® program, the symbol for the multi-pin plug distributor must be inserted in the program (cf. Figure 5.11).

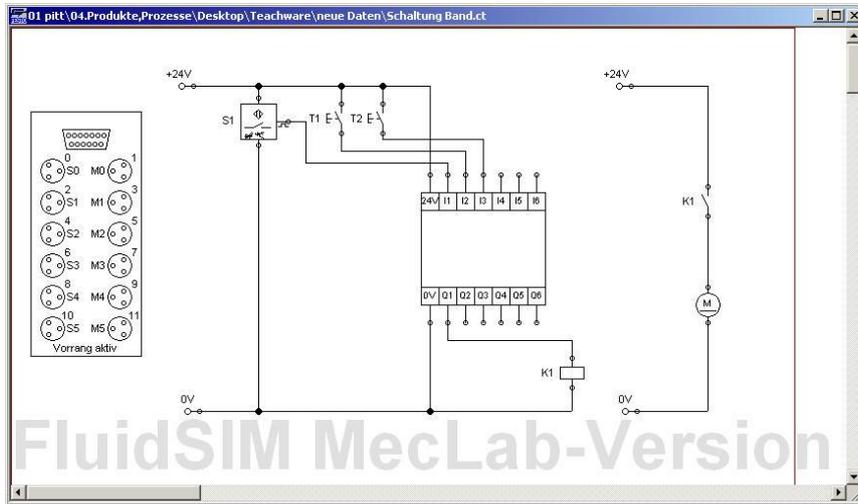


Figure 5.11: Program with multi-pin plug distributor

The labels in the symbol for the multi-pin plug distributor must now be adapted. To do this, open the symbol by double-clicking on it (Figure 5.12) and change the labels as per Table 5.1.

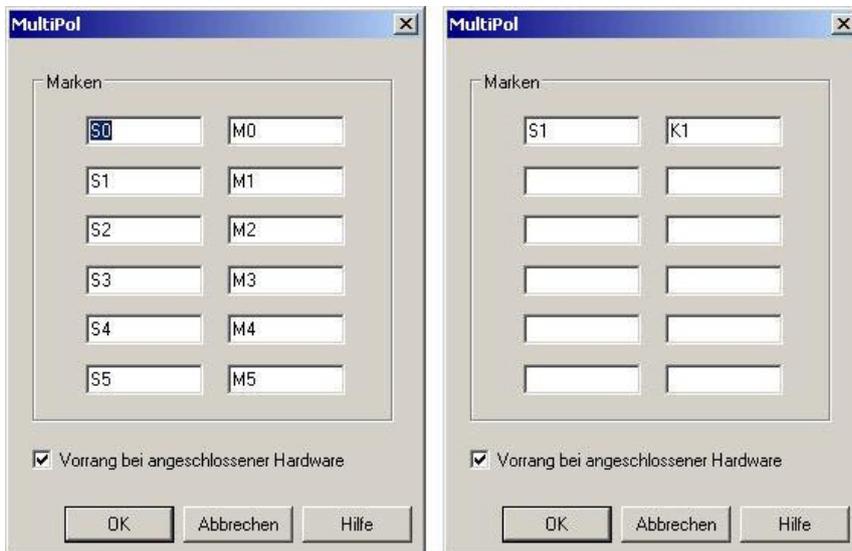


Figure 5.12: Multi-pin plug distributor dialog box before and after setting the labels

The labels must match those used in the electrical circuit diagram. The multi-pin plug symbol then establishes the connection to the station. It is of no importance what the labels are called. It is important, though, that the same label is used for the same element in the electrical circuit diagram and that this element is plugged into the correct slot on the multi-pin plug distributor.

Note

The "Priority when hardware connected" box must be ticked. This ensures that the signals for the actual sensors are used and not those simulated in the program.

If the simulation is now started and the pushbutton T1 actuated, the conveyor motor starts. The status of the input and output channels is indicated in colour on the multi-pin plug symbol. On the station's multi-pin plug distributor, the status of the input and output channels is indicated by LEDs.

The program can now be extended step-by-step to incorporate the other actuators into the station.

6 Handling station

6.1 Technical significance

Movement, orientation and assembly of workpieces are a requisite for all automated assembly systems. These tasks are performed by automated handling machines, the best known and most powerful of which are the industrial robots (cf. Figure 6.1).

Industrial robots are freely programmable and have at least four axes (i.e. driven joints), making them extremely flexible. Industrial robots are also very fast (over 1 m/s) and accurate (repetition accuracy of better than 50 µm).

Simpler handling devices are adequate for many assembly tasks.



Figure 6.1: Industrial robot (picture by Festo Didactic)

The following performance data is significant for all types of handling devices:

- number of axes,
- speed,
- accuracy,
- working space.

One of the most important components in a handling device are the grippers used to establish contact with the workpiece. There are many different designs of grippers:

- Mechanical grippers with two or three gripper jaws grip workpieces like a hand. Since these grippers' fingers are not as flexible as the fingers on an actual hand, however, it means that the gripper jaws generally have to be adapted to the workpiece to be gripped.
- Vacuum grippers hold the workpieces by means of vacuum. They are especially suitable for flat workpieces but less suitable for porous ones because no vacuum can be built up.
- Magnetic grippers for magnetisable workpieces.
- Adhesive grippers where the workpieces are held using an adhesive film. These are used less frequently because they are very sensitive to soiling.

Since two-axis automated handling machines are most frequently used to remove (pick) workpieces from a magazine and then deposit or assemble (place) them somewhere else, they are also called pick and place devices.

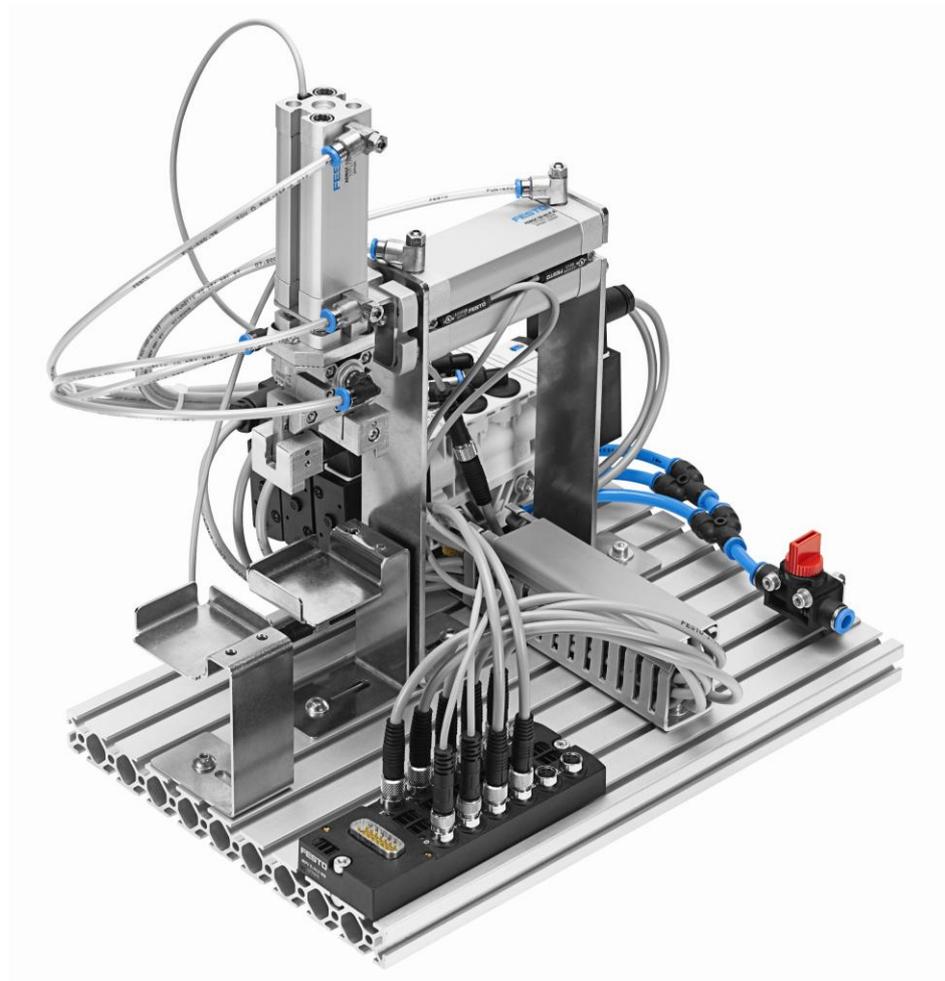


Figure 6.2: Handling station

6.2 Components of the handling station

The handling station consists of

- two pneumatic linear axes,
- one pneumatic gripper,
- three valves for controlling the pneumatic actuators,
- four magnetic proximity sensors for detecting the position of the axes and further components.

The following table provides an overview of the components, their significance and the corresponding circuit symbol.

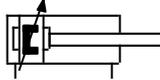
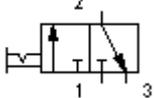
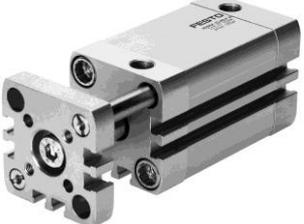
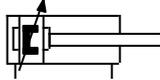
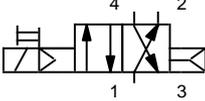
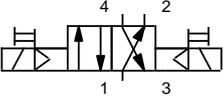
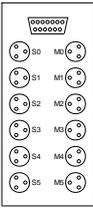
Illustration	Symbol	Description
		Gripper for holding the workpieces
		Magnetic proximity sensor for detecting the position of the cylinder piston
		3/2-way stop cock for shutting off the compressed air and exhausting
		T-distributor for distributing the compressed air
		Double-acting guided cylinder

Illustration	Symbol	Description
		<p>One-way flow control valve, used to regulate the speed of pneumatic drives</p>
		<p>4/2-way solenoid valve, with pneumatic spring return</p>
		<p>4/2-way double solenoid valve</p>
		<p>Multi-pin plug distributor, interface for connecting all actuators and sensors of the handling station to the control PC</p>

6.3 Commissioning the handling station

The handling station consists of a two-axis handling device that is fully adequate for simple assembly tasks.

Example

Joining the lid and base of a workpiece.

The handling station can perform numerous tasks:

- moving a workpiece,
- assembling the base and lid,
- sorting or assembly functions in cooperation with other MecLab® stations.

Integrated in the handling station is a mechanical two-jaw gripper whose gripper jaws have been adapted to the cylindrical workpiece. This gripper can be exchanged for a vacuum gripper that is available as an accessory.

The handling station is supplied fully assembled. It may, however, be necessary to readjust the holders for the workpieces so that the gripper can cleanly pick up and deposit the workpieces.

An aluminium profile plate with slots on which the individual components of the module are mounted using T-head nuts serves as the base for the handling station. All other components are likewise bolted on and can be disassembled and assembled using the supplied spanner and Allen key. The supplied screwdriver is primarily used to adjust the one-way flow control valves. The pneumatic tubing required can be cut to the correct length using the tubing cutter (do not use scissors or other knives as this can result in leaks).

For commissioning, the handling subsystem must be connected to the USB port of the PC using the EasyPort as well as to the power supply using the 24V power supply unit as described in Section 3.

Correct wiring of the actuators and sensors must be ensured if the supplied sample programs are to be used. The correct pin assignment is described in a schematic diagram in the sample program.

6.4 Executing a simple task using the handling station

In a production line, the handling station often represents the interface between two workstations. It can carry out the conveying of workpieces between two stations. The following sample exercise explains step-by-step the mode of operation of the FluidSIM® software as well as its interaction with the handling station.

The presented solution process is just one possible version of a solution and is only provided as a means of explaining the system.

Task

Develop a computer-aided manual control with the following functions:

- Advance the x-axis when a pushbutton is actuated, but only if the cylinder is in the retracted end position.
- Retract the x-axis when a pushbutton is actuated, but only if the cylinder is in the forward end position.

Procedure for solving the task

The solution to this task can be broken down into five phases:

1. Initial considerations and schematic diagram
2. Assignment tables for the components
3. Circuit diagram creation and programming using FluidSIM®
4. Testing with FluidSIM® via simulation
5. Testing the program on the actual handling station

Initial considerations

- Schematic diagram of the handling setup

To start it is a good idea to produce a schematic diagram of the mechanical setup to identify the position of the sensors and actuators. A possible schematic diagram of the components involved in the task could look something like Figure 6.3. The schematic diagram can be drawn by hand or created using a computer.

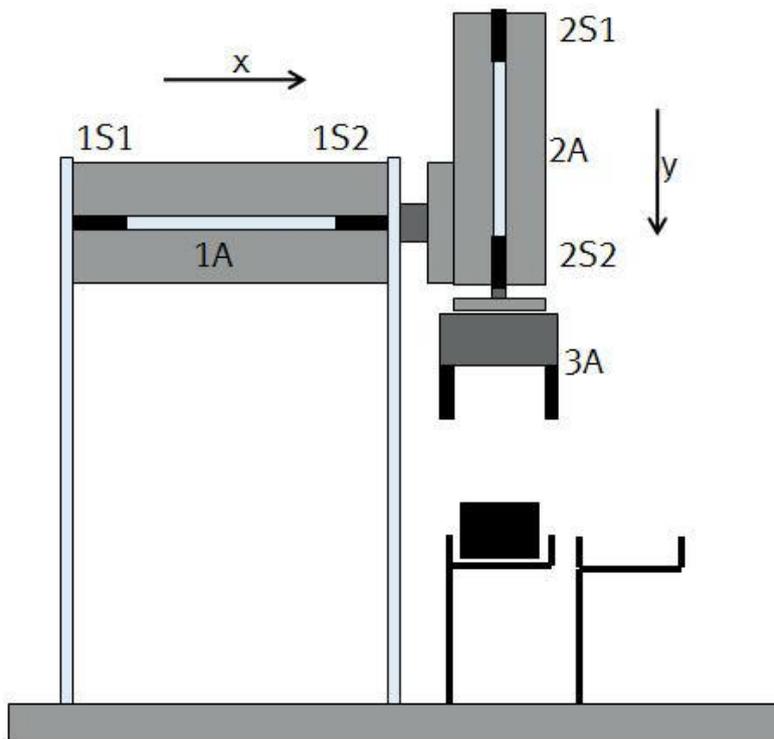


Figure 6.3: Schematic diagram of the handling station

- Pneumatic circuit diagram

It is also a good idea to produce a pneumatic circuit diagram as well as an assignment table for the input and output signals. This circuit diagram can be created using FluidSIM® or drawn by hand.

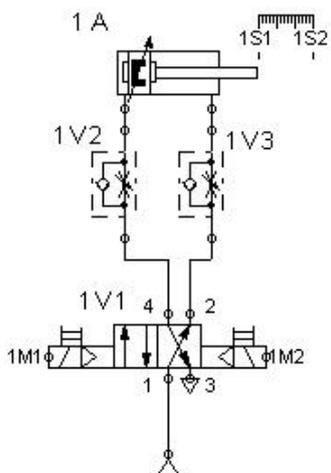


Figure 6.4: Pneumatic circuit diagram (x-axis only)

Slot	Assignment	Description
0	1S2	Sensor for forward end position
2	1S1	Sensor for retracted end position
1	1M1	Valve solenoid (advance cylinder)
3	1M2	Valve solenoid (retract cylinder)

Table 6.1: Assignment table for the handling station

Analysis of the task

Before starting programming, you should be clear about the task. To ensure this, it is a good idea to describe the task in your own words or to create a flow chart.

- The piston of the horizontal, double-acting cylinder is to advance from its normal position (retracted). The command for this is issued via a pushbutton in FluidSIM®.
- The cylinder may only advance, however, if it is in the retracted end position. This can be queried using the proximity sensor. This proximity sensor is labelled 1S1 in the schematic and circuit diagrams.
- The return stroke is also to be executed by means of a pushbutton signal. In this case too, the cylinder may only retract if it was previously fully advanced.
- The sensor for the forward end position is labelled 1S2 in the schematic diagram.
- Two pushbuttons for operation are needed in the FluidSIM® program.
- The horizontal cylinder is activated using a 4/2-way double solenoid valve. Switching on the valve solenoid 1M1 advances the cylinder, switching on the valve solenoid 1M2 retracts the cylinder. Since the valve is a double solenoid valve, a short current pulse is sufficient to keep the valve (and thus also the cylinder) in the respective switching position.

Circuit diagram creation and programming using FluidSIM®

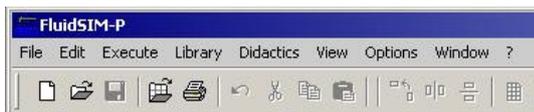
The supplied FluidSIM® software is used for programming. This enables the circuit to be simulated first on the computer. If the simulation does not reveal any errors, then the station can be directly activated and operated.

Since the test setup consists of electrical and pneumatic components, a circuit plan must be created in the FluidSIM® program for both system components. It is recommended to create the pneumatic circuit diagram first, followed by the electrical circuit diagram.

Step 1: Opening FluidSIM®

In preparation for creating the circuit diagram, it is first necessary to create a new page to get an active workspace. To this end, FluidSIM® must be opened by double-clicking on the program icon:

- Call up a new workspace
Click on the blank white page on the left in the second menu bar (or on "File > New").
A new empty workspace for a controller appears.



- Save the new controller
To do this select "File > Save As ..." in the menu bar and save the file to the desired location on a data storage medium under a user-defined name.

Step 2: Inserting the components

The components needed to create the pneumatic circuit diagram are located in the toolbar on the left side of the screen. They are inserted in the circuit diagram by:

- clicking on the appropriate symbol,
- keeping the left mouse button pressed,
- dragging the symbol to the required location in the circuit diagram and then releasing the mouse button.

The pneumatic system consists of a double-acting cylinder, a 4/2-way double-solenoid valve, two one-way flow control valves and the compressed air supply. Figure 6.5 shows the components in the workspace.

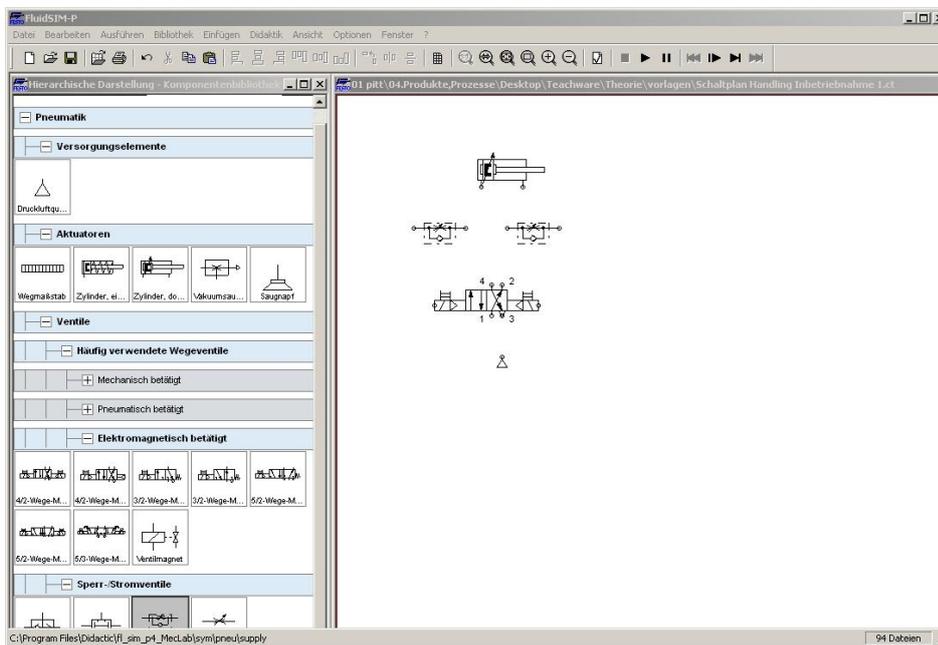


Figure 6.5: Components of the pneumatic circuit diagram

Step 3: Rotate the one-way flow control valves

The one-way flow control valves should be rotated to produce a clear circuit diagram. To do this, right-click on the symbol for the one-way flow control valve in the workspace; in the context menu that opens, select the menu item "Rotate" followed by "270°".

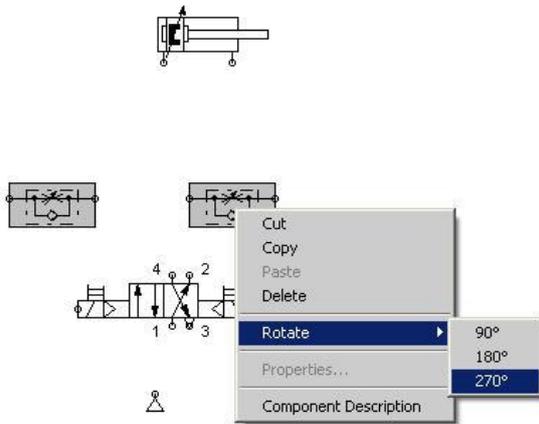


Figure 6.6: Rotating the one-way flow control valves

Step 4: Install tubing between the components

Next, the tubing between the components must then be installed. This is done by dragging the mouse over a node point of the symbol until a crosshair is displayed. With the left mouse button pressed, move to the required node point of the next symbol. Release the left mouse button as soon as the crosshair symbol confirms the connection.

The pneumatic circuit diagram then looks as follows:

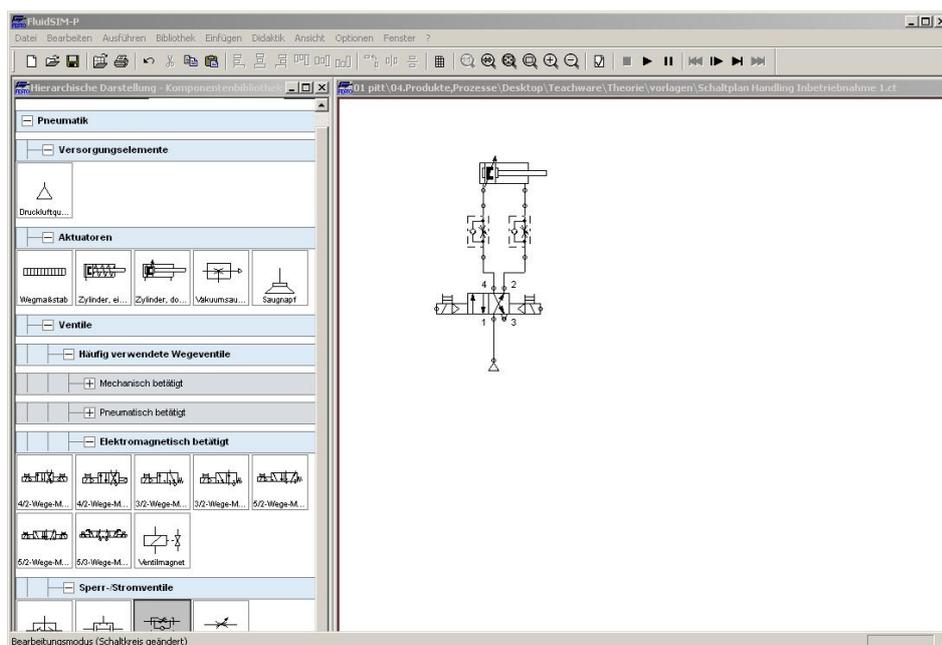


Figure 6.7: Installing the tubing for components

Step 5: Set labels and insert proximity sensors

Labels need to be set so that the link with the electrical circuit diagram and the actual hardware can be established later. These labels are needed for all electrical components, i.e. valve solenoids and proximity sensors.

To label the valve solenoids, right-click on the valve solenoid and select the menu item "Properties". Enter the valve solenoid designation in the "Label" field, in this case 1M1 and 1M2 (for the first or second valve solenoid respectively of the first valve).

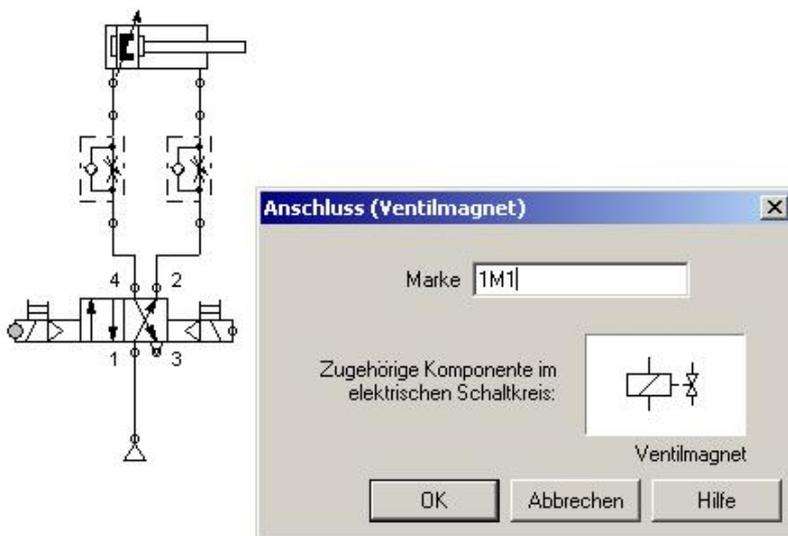


Figure 6.8: Entering a label for the valve solenoid

To mount the proximity sensors on the cylinder, right-click on the cylinder. A window opens where you can enter the proximity sensors mounted on the cylinder and their position.

There are two proximity sensors on the cylinder; one in the retracted end position and one in the forward end position. The position of one of the proximity sensors is therefore 0 mm, the position of the other 100 mm. The proximity sensors are labelled 1S1 and 1S2 (for the first and second proximity sensors of the first cylinder).

Clicking on "OK" closes the input window again.

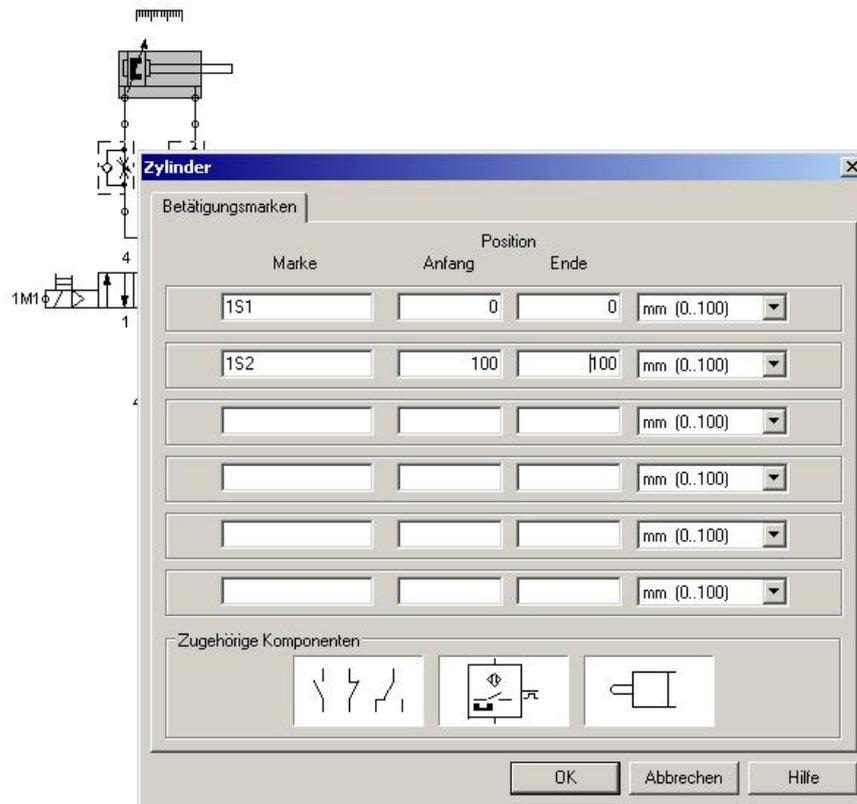


Figure 6.9: Entering the proximity sensors

Step 6: Test the pneumatic circuit

The simulation is started by clicking on the Start button. If one of the two manual overrides is clicked on, the valve reverses and the cylinder retracts or advances.

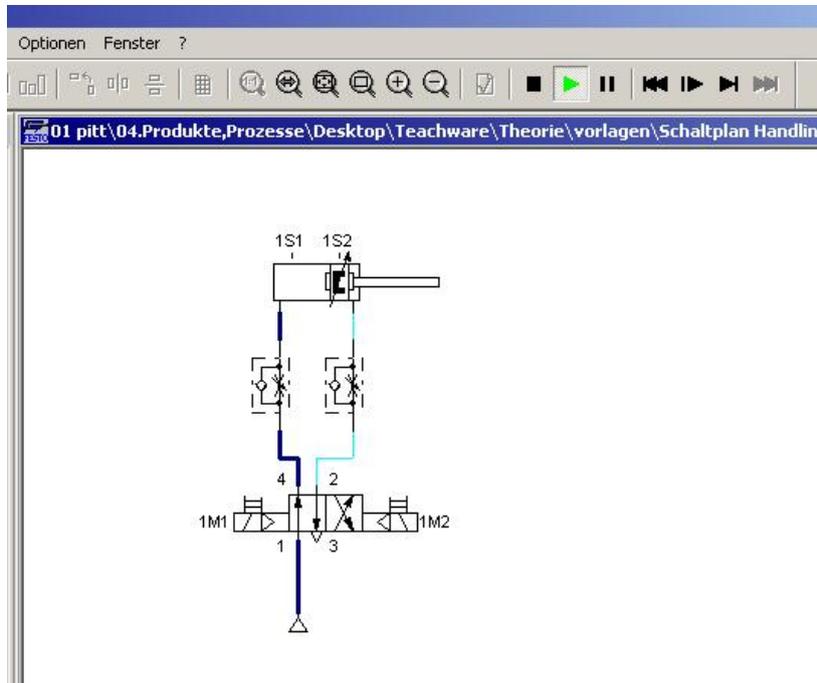


Figure 6.10: Simulating the pneumatic circuit diagram

Step 7: Components and wiring of the electrical circuit

The components of the electrical circuit are inserted and connected in the same way as the pneumatic components.

The workspace should look as follows after the components are inserted and wired:

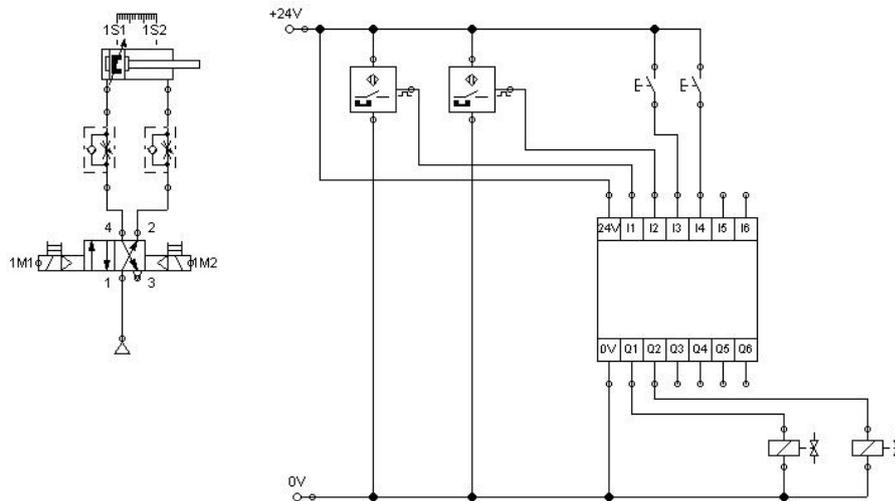


Figure 6.11: Inserting and wiring the electrical components

Step 8: Assign labels

To connect the electrical and the pneumatic components, the electrical components must also be labelled.

This is done in the same way as for the pneumatic components, i.e. by right-clicking on the component and entering the labels in an input window. Labels are needed for the valve solenoids and the sensors.

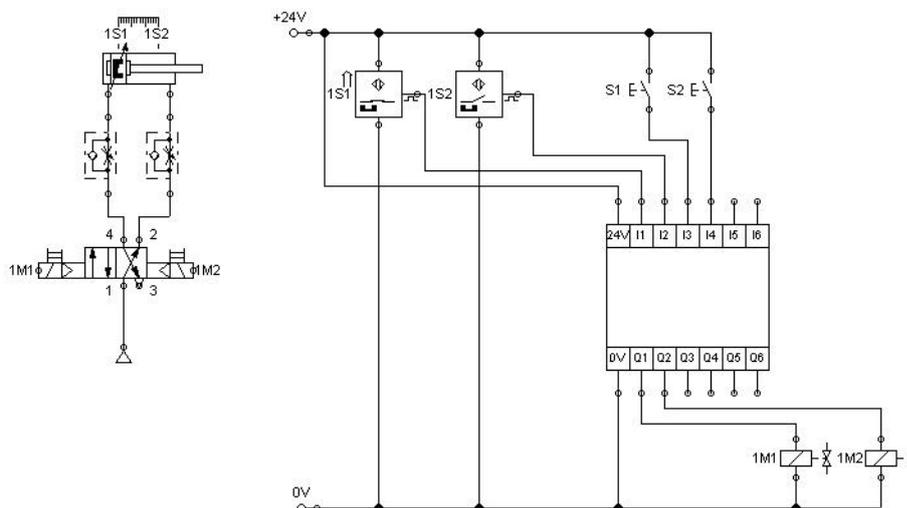


Figure 6.12: Assigning labels for the electrical components

In addition, the two pushbuttons are labelled with S1 and S2.

Step 9: Create the control program

To be able to enter the control program in the digital module, the digital module must be opened by double-clicking on it. A new window containing the digital module's input and output channels is displayed.

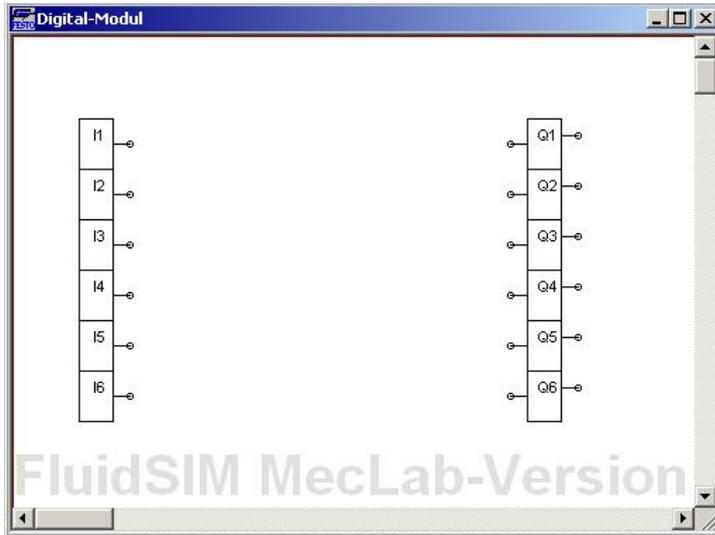


Figure 6.13: Input and outputs channels of the digital module

On the left side are the inputs marked I1 to I6, on the right side the outputs marked Q1 to Q6. You now link the inputs and outputs using logic modules. These are in the toolbar on the left side of the screen and are dragged to the workspace like all other components.

The task demands that the cylinder retract or advance when the respective pushbutton is actuated and the cylinder has reached the relevant end position:

- Valve solenoid 1M1 is switched on when pushbutton S1 and proximity sensor 1S1 are actuated.
- Valve solenoid 1M2 is switched on when pushbutton S2 and proximity sensor 1S2 are actuated.

This means that two AND gates are needed in the program. Since the AND gate in FluidSIM® has three inputs, two high gates are used so that the third, redundant one can always be set to high. Otherwise FluidSIM® would issue an error message that there is one unassigned input.

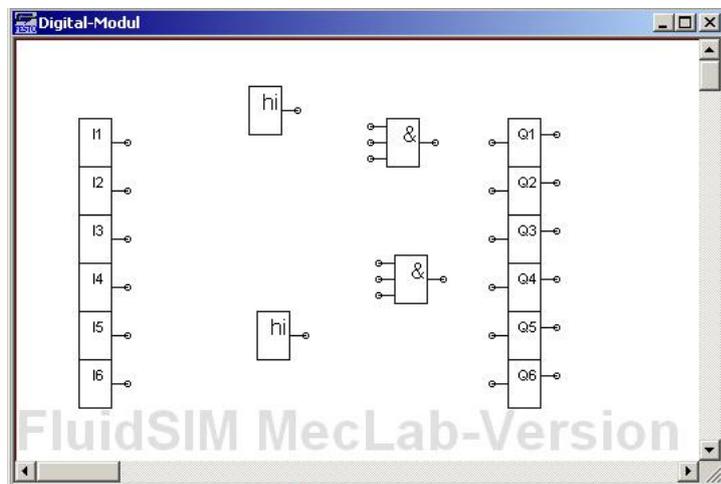


Figure 6.14: Digital module with logic gates

Note

Unassigned AND gate inputs are always set to high in FluidSIM®.

The logic gates are now connected and the logic program therefore created (cf. Figure 6.15). Closing the input window stores the program in the digital module (or PLC). The simulation can be started after the window closes.

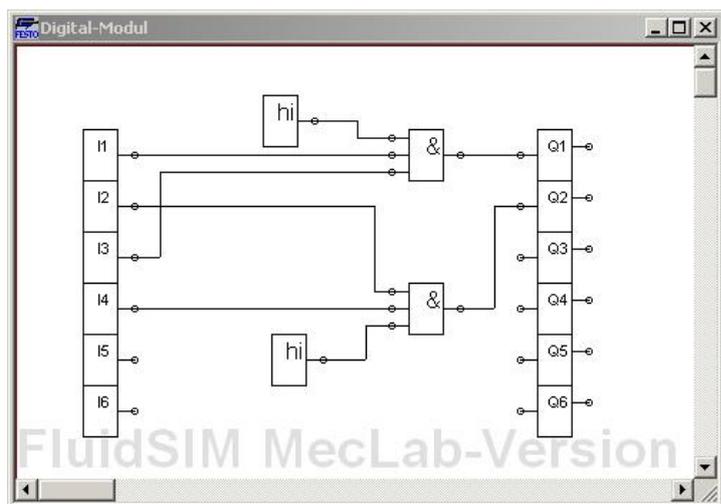


Figure 6.15: Complete logic program

Testing the solution via simulation

The simulation is started by clicking on the Start button. If pushbutton S1 is then actuated, the cylinder advances in the simulation, pushbutton S2 retracts it again.

Note

The cylinder cannot be reversed until it has reached the respective end position.

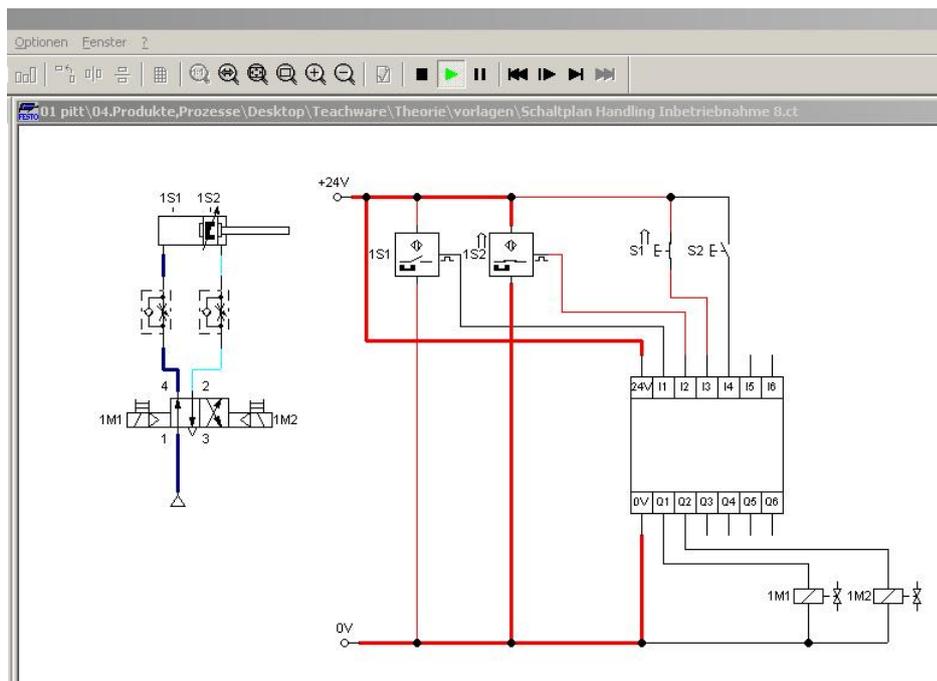


Figure 6.16: Simulating the circuit

Testing the solution on the actual handling station

To connect the handling station to FluidSIM®, the EasyPort must be plugged into the multi-pin plug distributor on the station and this must be connected to the PC (using the USB cable) and to the power supply.

The symbol for the multi-pin plug distributor is then dragged into the workspace in the FluidSIM® program.

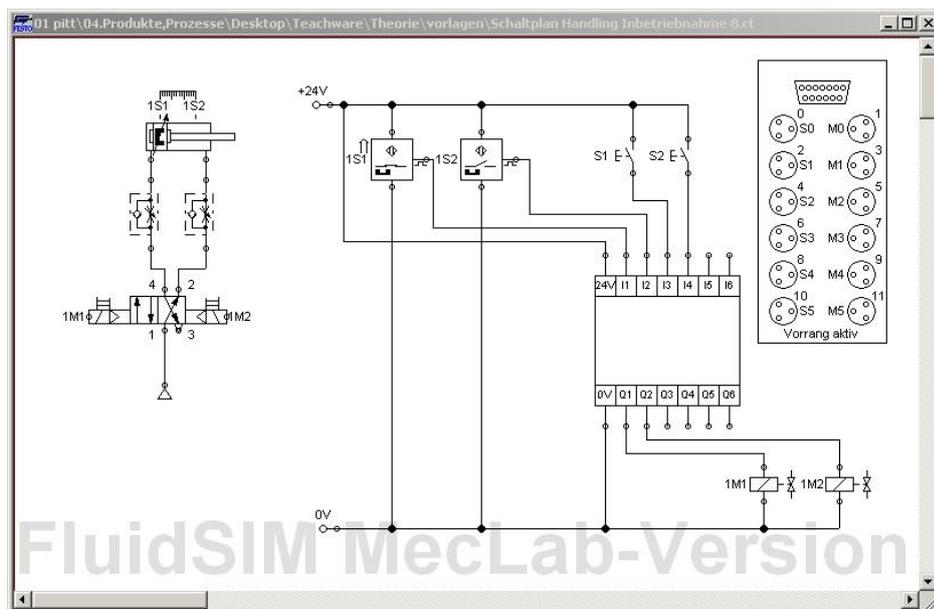


Figure 6.17: Multi-pin plug distributor symbol for connecting the station

The labels in the symbol for the multi-pin plug distributor must still be adapted. To do this, open the symbol by double-clicking on it (Figure 6.18).

Labels are then modified as per Table 6.1. The labels must match those used in the pneumatic and electrical circuit diagrams. The multi-pin plug symbol then establishes the connection to the station. It is of no importance what the labels are called (1M1 is the usual designation in engineering; the label could also be called "left valve solenoid"). It is important, though, that the same labels are used for the same component in the pneumatic and electrical circuit diagrams and that this component is plugged into the correct slot on the multi-pin plug distributor.

Note

The "Priority when hardware connected" box must be ticked. This ensures that the signals for the actual sensors are used and not those simulated in the program.

If the simulation is now started and the pushbutton S1 is actuated, the cylinder in the station is advanced. The status of the input and output channels is indicated in colour on the multi-pin plug symbol. On the station's multi-pin plug distributor, the status of the input and output channels is indicated by LEDs. The program can then be extended step-by-step to incorporate the other actuators and sensors into the station.



Figure 6.18: Dialog box of the multi-pin plug distributor before the labels are changed



Figure 6.19: Dialog box of the multi-pin plug distributor with the labels changed

The schematic diagram, the circuit diagram and the logic program together form the technical documentation for the project. These can be supplemented with operating instructions and data sheets if necessary.

7 Tips for designing lessons

7.1 Overview of the supplied media

The MecLab[®] learning system consists of three components:

- training hardware,
- FluidSIM[®] programming and simulation software,
- learning materials.

The learning materials consist of the following:

Theory section

The theory section covers the key fundamentals of automation technology and mechatronics. It contains information on sensors, pneumatic and electric drives, relay controllers and programmable logic controllers. It also includes a section on the history of automation technology and on how engineers work. This document is stored as a pdf file. Along with MecLab[®], you can print out this file and distribute it to your students. You cannot, however, modify the content.

Commissioning instructions (this manual: "Working with MecLab[®]")

The commissioning instructions consist of a didactic introduction as well as detailed step-by-step instructions on how to assemble and commission the three MecLab[®] stations. It is recommended to replicate the station setup contained in this document.

This document is stored as a pdf file. Along with MecLab[®], you can print out this file and distribute it to your students. You cannot, however, modify the content.

Set of exercises

The set of exercises contains several exercise sheets for each station, ranging from simple ones for learning about the components, their function and symbols through the creation of schematic diagrams and circuit diagrams to complex programming exercises. The exercises build on each other and the knowledge required to complete them increases with each one. Every exercise includes a brief description of the learning objectives. The exercise sheets are designed for direct use by the students as worksheets. The worksheets are available as Word files; you are free to modify them and adapt them to your requirements as appropriate.

The theory section covers the required fundamentals.

Presentation

Also supplied is a presentation in PowerPoint format (*.ppt). This essentially contains the illustrations from the theory section; these can be used as explanations during a lecture or to create your own documents.

Training hardware

The training hardware consists of the three stations, the EasyPorts, the necessary cables, workpieces and tools. Some of the exercises in the supplied worksheets call for the conversion of the stations, for example changing or relocating sensors, attaching or removing actuators. Adjustment of sensors may also be necessary.

The stations are designed in such a way that components can be swapped between them, for example:

- the sensors from the conveyor station can also be used in the stacking magazine or handling stations,
- the stamping unit from the stacking magazine station can also be attached to the conveyor.

In addition, it is possible to combine the stations into an assembly line. This, however, also calls for conversion and/or relocation and adjustment of the components.

FluidSIM® programming and simulation software

The FluidSIM® programming and simulation software on the supplied CD-ROM is tailored to the functions of MecLab®. The software is installed on the PC from the CD-ROM and is then ready to use.

7.2 Lesson design

It is not possible at this point to provide binding guidelines on how to use MecLab® in a lesson. We can, however, refer to information gained from an in-school pilot test of MecLab® in 10 general secondary schools in Germany. This pilot scheme showed that the use of realistic media such as MecLab® resulted in a high level of motivation in most students. This would only be the case, though, if the students have proper access to the stations.

MecLab® should not, therefore, be restricted to use as a medium for teaching programming techniques but also for dealing with the mechanical aspects, i.e. the setup and conversion of the stations. Due to the constraints in most schools, however, it is unfortunately not possible to fully realise this aspect.

Lessons can be roughly divided into three phases:

- preparatory phase,
- project phase,
- follow-up and assessment.

7.2.1 Preparation

Students generally have no direct access to industrial production and therefore no direct relationship with this topic. Hence it is advisable to take the students to see an automated production facility before starting to work with MecLab[®]. The exact nature of the production facility is of little importance.

It is important that students recognise that an automated assembly system always includes functions for

- conveying,
- handling,
- magazining and feeding

workpieces. These basic functionalities are also present in MecLab[®].

For that reason, the following questions should be discussed with the students before the visit:

- How important is automation technology nowadays? Where is automation found in our day-to-day lives?
- What prompts companies to start using automation technology? What consequences does its use have?
- What functionalities are found in automated production systems?

These questions can also be addressed on-site in the company visited (and should therefore have been prepared in advance of the visit).

If a visit to an actual production facility is not possible, the videos supplied in the Videos directory on the CD-ROM can be used for the same purpose.

In the follow-up phase, the results should then be finalised and, above all, the connection with the learning system made:

- Which functions are found in the stations?
- Which components were also present in the actual production facility?

7.2.2 Group work

MecLab[®] is designed in principle for project-based teaching in small groups. The optimum group size has been found to be 2 to 3 students. Each group should be equipped with a station and a PC with FluidSIM[®].

Before starting the group work, it is a good idea to give a general introduction into using FluidSIM[®], connecting the stations to the PC and also the function of the most important components. Students must also be made familiar with the safety information.

The project work can be introduced with an explanation about certain topics, for example sensors, pneumatics, circuit or programming technology. The information in the theory section, the supplied PowerPoint presentation and the animations on CD-ROM and in FluidSIM[®] can be used for this.

The information can be delivered in the form of a lecture by a teacher or presented by the students themselves. The Internet, and especially the online encyclopaedia Wikipedia, can also be a good source of information, especially for the students.

Alternatively, students can acquire the information they need to complete the exercises within the framework of the project work. In this case, it is particularly useful to allow the students to present their results once the exercises have been completed.

This is especially important given the fact that the subject matter with the various stations is similar, but not completely identical. The presentations help to ensure that all students have the same level of knowledge.

The exercises become increasingly challenging. Table 7.1 provides an overview of the learning objectives of the exercises.

On the whole, it can be said that the stacking magazine station is the one with the easiest exercises and the handling station the one with the most complex exercises. The conveyor station is somewhere in the middle.

The time required to complete each exercise varies from 1 to 4 lessons depending on the level of difficulty, school type, age group or preparation.

No.	Stacking magazine	No.	Conveyor	No.	Handling industry
1.0	Components and their function	2.0	Components and their function	3.0	Components and their function
1.1	Learning about symbols and components	2.1	Learning about symbols and components	3.1	Learning about symbols and components
1.2	Function of components	2.2	Learning about symbols	3.2	Learning about circuit diagrams
1.3	Schematic diagrams, technical drawings and circuit diagrams	2.3	Introduction to sensors	3.3	Schematic diagrams, technical drawings and circuit diagrams
1.4	Selecting cylinders and valves, creating circuit diagrams, controlling single-acting cylinders	2.4	DC motor, actuation	3.4	Selecting valves and actuating elements, flow control of cylinders, proximity sensors, actuating double-acting cylinders
1.5	Schematic diagrams, circuit diagrams, flow control of cylinders, controlling double-acting cylinders	2.5	Logic operations	3.5	Logic operations
1.6	Circuits with relays and time relays, logic operations	2.6	Simple program using logic modules	3.6	Simple sequencing using logic modules
1.7	Proximity sensors, simple sequencing using relays	2.7	Complex program using logic modules	3.7	Complex sequencing using logic modules

Table 7.1: Content of the sample exercises

7.2.3 Alternative scenario to group work

It goes without saying that it is not always possible to provide each group of 2 to 3 students with their own station. Group sizes of more than 3 students have proven to be inefficient. A different approach is therefore recommended if there are more than 3 students per station:

- Introduction and facility visit (alternatively video) as described in Section 7.2.
- Instead of group work, the students work through the worksheets theoretically, create their solutions in FluidSIM® and only test them using the station if the solution works correctly during the simulation.
- With this approach, the students can work constructively alone or in pairs. Each student (or group respectively) should have a PC with FluidSIM® at their disposal.
- The disadvantage of this approach is that students have very little opportunity to make mechanical modifications to the stations. The lesson is then very much restricted to the programming aspect.
- The advantage is that up to 20 students can easily work with three stations. Furthermore, all students are working on the same exercise.

7.2.4 Follow-up and assessment

Completion of the project exercises should be followed by a phase of reflection. As part of this process, the students can present what they have learned about the mode of operation of the stations and the sensors, actuators and control algorithms used in the stations, if they have not already done so, and together draw a comparison between the stations.

In doing so, the students should start to realise that automated systems always involve the interaction of sensors, actuators and controllers.

It also makes sense to mirror the lessons learned with the results gathered in the preparatory phase.

Ideas for further projects can also be gathered during this phase. See the next section for more suggestions.

7.2.5 Further-reaching projects

The supplied exercise sheets are intended as an introduction to the topic of automation. They show how the stations work and how they are programmed.

The problem definitions in the exercises have a very strong engineering bias, i.e. the technical solution is directly addressed. The exercises can, however, be made more realistic if the teacher assumes the role of "customer" and commissions a group of students to supply a station (or a "production line") with a specific functionality. The students then need to plan, execute and document (e.g. including operating instructions) the project and hand over the "product" to the customer. This can take place, for example, in the form of a presentation.

There is no sample solution for these problem definitions, which is entirely intentional. There are normally always several options for fulfilling a technical task. They should be assessed using criteria such as:

- function (was the technical function fulfilled),
- economy (what expenditure was involved),
- adherence to deadline (was the schedule adhered to),
- documentation (are there circuit diagrams, schematic diagrams, parts lists, programs, operating instructions available, depending on the problem definition),
- project management, team work (how did the students work together, were all the students in the group included or did one student do everything).

A (non-complete) listing of project ideas follows which go beyond the supplied exercises, together with a suggestion for the technical solution. These project ideas fall into one of two categories: extending the functionality of individual stations and linking several stations to form a production line.

Extending the functionality of stations

This is mostly done by means of additional components (taken from other stations) or by means of modified programs.

Here are a few examples for the extension of stations:

- Empty magazine warning with the stacking magazine station
 - Fill level monitoring using a through-beam sensor
- Pushing out new workpieces only as long as the stacking magazine is full
 - Fill level monitoring using a through-beam sensor
- Warning of incorrectly inserted parts in the stacking magazine station
 - Monitoring using an inductive sensor (metal workpieces)
- Conveyor with buffer function (stopping a part for x seconds)
 - Attachment of the deflector to the opposite side of the conveyor
- Extending the conveyor to include a stamping function
 - Attachment of a stamping unit to the conveyor, conversion
- Y-axis of the handling station with a stop at the half stroke
 - Proximity sensor from the stacking magazine station for detecting the position in the cylinder mid-section, actuation by means of two 3/2-way solenoid valves to facilitate stopping.

In addition to the suggested conversions, an appropriate program must be created for each solution.

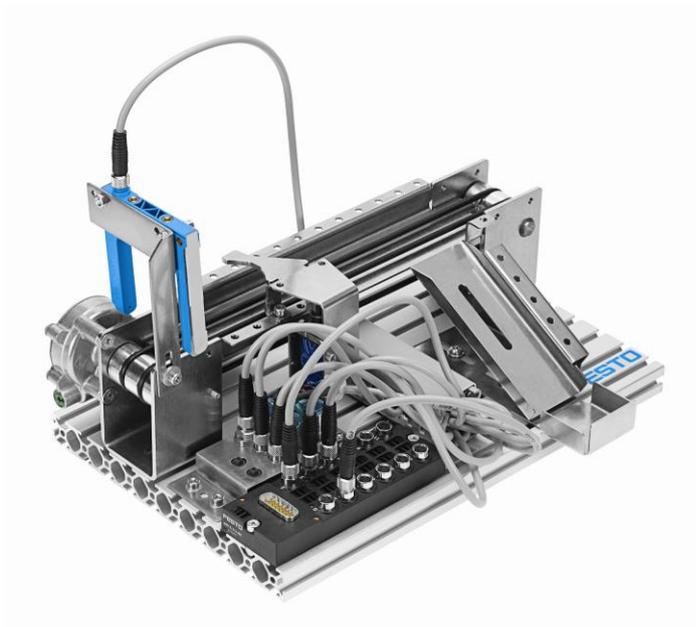


Figure 7.1: Conveyor with stopper function

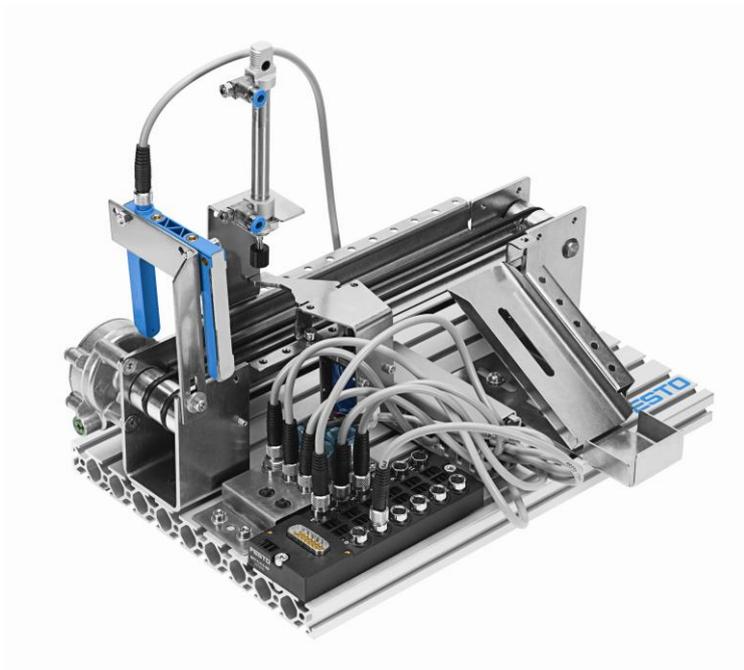


Figure 7.2: Conveyor with stamping function

Combining the stations to form a production line

In this exercise, students have to solve problems relating to interface. The components must be aligned so that a mechanical handover of the workpieces is possible. Equally important is the establishment of a data link between the stations. Since the stations are controlled by different PCs, data has to be exchanged so that each controller knows when which action is required.



Figure 7.3: Linking several stations

If one or more stations are to be linked, data must be able to be exchanged between the stations. There are basically three options for this:

1. Two stations are controlled via only one PC. For this to be possible, all signals from both stations must be wired to one multi-pin plug distributor.
2. Sensors in the stations detect when workpieces enter or leave the processing area. In this case, the stations actually work independently of each other. The programming must ensure that no collisions can occur.
3. Data exchange between the controllers. To this end, a special cable is placed between the input of one multi-pin plug distributor and the output of the other multi-pin plug distributor. When the output is activated, the other controller can process this like a sensor signal. This facilitates simple communication between the controllers.

8 Project work

8.1 Objectives of the project lesson

The project lesson is a lesson form in which work is performed on projects with or without a binding didactic concept. For the students, the project itself is the goal towards which all actions are directed. For the teacher, it is a way of encouraging students to work on their own (e.g. planning, executing and evaluating). The project lesson is a type of activity-oriented lesson. It offers the opportunity to go beyond the purely technical level and to encourage active and constructive thought processes. The project lesson is thus a comprehensive means of developing active competence.

To design an individual and sophisticated learning process, the exercises and problem definitions for the project lesson should be comprehensive, but above all representative of practical applications or the students' frame of reference.

The project lesson is usually structured around a specific schedule that is divided into different phases. It is the teacher's decision, however, to follow these suggestions or modify them depending on the situation.

8.2 Characteristics of the project lesson

Project work as an open lesson form requires the teacher to roughly sketch out the sequential structure based on the subject matter of the project, the students' capabilities and the conditions under which the project is to be carried out. At the very least the teacher needs to work out the framework of a sequential structure.

A lesson can be described as open if the subject matter as well as the manner in which it is learned is not prescribed and students can follow different solution processes they themselves have defined.

The term "project lesson" is often used very freely. There are characteristics that define and describe this type of method. The project lesson does not necessarily have to exhibit all of these characteristics but should include a majority of them:

Practice-oriented

Students should recognise the units of theory and practice. They can either gain this at the start of the project work or experience it while working on the project.

Interdisciplinary

The complex nature of the project lesson requires the inclusion of several scientific disciplines or fields. The engineering sciences are intrinsically multi-dimensional and focus on creative problem solving. They start with a means-end analysis and orient themselves towards what is physically possible, economically prudent, ecologically sustainable and humanly desirable. To put it another way, work on technical projects is driven by human need and technical action, both of which have conflicting objectives.

Encourages self-organisation, self-responsibility and thought-out and planned independent work

Students should work on their own as much as possible during the project lesson. This will enable them to plan, execute and evaluate their work on their own, and thus develop their own learning and working style. The teacher keeps a low profile and acts primarily as a moderator, observer and, if necessary, advisor if requested to do so or if required to do so for safety reasons.

Demands and encourages different social and organisational forms

The project lesson encourages team work, group-planned individual work and especially self-regulated individual work. The teacher can deliberately steer towards a particular form of work or the structure can develop spontaneously. Project work needs to be organised in different ways depending on the subject matter.

The following four versions have proven suitable:

Parallel work by a number of teams working on the same project

All the teams are subject to the same conditions. The different project solutions are assessed at the end.

- Separate/joint team work on the same project

The groups work separately on the same project in the initial phase. Each group presents its results. The decision about which proposed solution to use is made jointly. The project is concluded jointly.

- **Joint-separate-joint work on the same project.**
Students discuss together the subject matter of the project and the different ways of working on it. The overall project is broken down into subtasks and subproblems to be solved are defined. The teams decide themselves which subproblems they want to solve. Each team presents its solution to the class. Following an evaluation round, the project is concluded jointly.
- **Parallel work by a number of teams, each working on different projects**
With this method of organising the project work, suitable projects must be selected and assigned to existing teams. The project topics should not be too demanding or too easy for the team members. They must match the performance level of the respective group.

Problem solving processes

An important characteristic of the project lesson is the problem solving process. In order to meet the objective of the activity, the student has to progress from preparing the task to solving the problem by using previously learned knowledge and expertise while also gaining new skills and abilities.

Purpose- and goal-oriented

In engineering, all activities are performed with a specific goal in mind. For the students, the subject matter of the project (e.g. a controller for automating a process) is the goal. If they recognise that new technical knowledge is required to reach this goal, they are intrinsically motivated to acquire the necessary skills and abilities on their own, because they recognise their importance in achieving the goal.

For the teacher, the subject matter of the project is less important per se. It is a means to an end, a medium to be learned and worked on and that helps to achieve the educational objectives. Ultimately the important aim is to develop the students' active competence and all this entails.

8.3 Phases of the project lesson

To be able to effectively complete a project on their own, the students not only need certain technical knowledge, they also need to be methodical and should already have a certain amount of experience in solving problems on their own. This means that they:

- are familiar with problem solving strategies, from identifying the problem to evaluating the solution,
- have basic problem solving abilities,
- have developed self-confidence in dealing with problems,
- have the readiness, willingness and persistence to grapple with problems even if they experience setbacks.

The model of the problem solving process can be used when planning and completing the project lesson, although the teacher is free to deviate from it.

8.3.1 Deciphering and understanding the problem (preparatory phase)

This preparatory or information phase is about defining the problem in an ideal case, in other words students find the project idea and derive the concrete project tasks from it. The project goal must be defined. If it is the students' first project lesson, the teacher must inform them of the purpose of project work and how it is carried out. The preparatory phase should be kept as short as possible so as not to deflate the students' motivation.

8.3.2 Identifying possible solution processes (evaluation phase)

In the evaluation phase, the students must identify possible solution processes to reach the goal and rate them against each other. The solution approaches must be compared with the material conditions and the students' capabilities and competencies. The chosen approach should represent a certain compromise between what is technically intended and economically prudent and what the material conditions and human resources can support.

8.3.3 Planning a solution process (planning phase)

The students' task in the planning phase is to plan and organise the entire sequence, i.e. the individual steps required to reach the goal. This includes material planning (tools, materials, sundry materials) as well as planning of human resources (number of groups, size and composition of the groups). Project subgoals and the methods to achieve them can be defined and project (sub)groups to solve concrete subtasks formed.

8.3.4 Realising the project solution (interaction phase)

During the interaction phase, the students work on solving the project subgoals in their respective subgroups. The teacher's main role in this phase is to ensure that all necessary information is available. The results should be documented by each group and prepared for the presentation.

8.3.5 Evaluating the problem solution (presentation phase)

In the presentation phase, the members of the individual project subgroups present the results of their work to the entire project team or class. In addition to presenting the concrete product of their activity (e.g. finished controller), each group should also give a report on their experiences with the procedure in the group, any errors and problems that occurred and how they were solved. The teacher's role is mainly that of a moderator in this phase.

If several solution approaches have been elaborated, these should be evaluated and a decision made about the best one. This must be compared with the project goal defined in the planning phase. An exchange of experiences and an evaluation of all the project work can then take place. This concluding discussion can result in finding new sequences and organisational structures for future projects.

Solving a problem through project work frequently leads to the emergence of new problems; the students will have to stretch themselves to solve these. This will test their skills and abilities as well as the outcome of the new project-oriented problem solving process. The students' active competence increases with each project they complete.

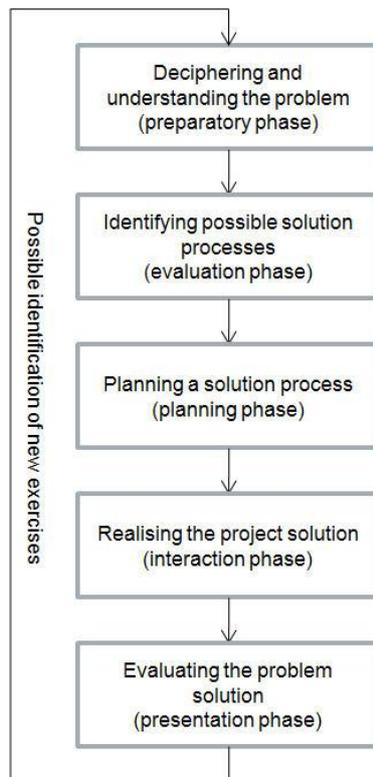


Figure 8.1: Phases of the project lesson