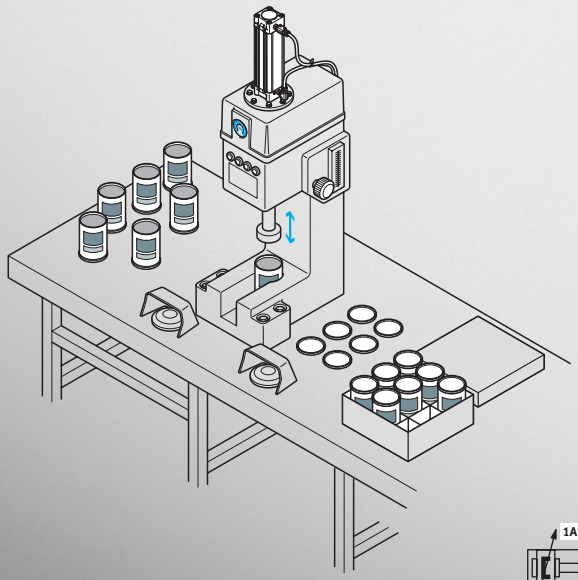
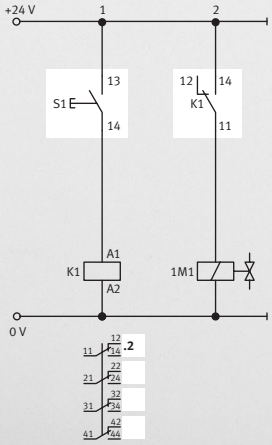
Electropneumatics
Basic level

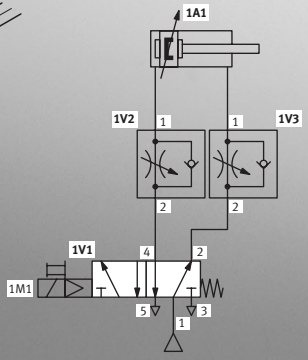
FESTO

Workbook
TP 201

With CD-ROM







Festo Didactic
541090 en

Use for intended purpose

The training system from Festo Didactic has been developed and produced exclusively for training and further education in the field of automation and technology. The respective training companies and/or trainers must ensure that all trainees observe the safety precautions which are described in this workbook.

Festo Didactic hereby excludes any and all liability for damages suffered by trainees, the training company and/or any third parties, which occur during use of the equipment in situations which serve any purpose other than training and/or further education, unless such damages have been caused by Festo Didactic due to malicious intent or gross negligence.

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Preface

Festo Didactic's training system for automation and technology is geared towards various educational backgrounds and vocational requirements. The training packages are therefore broken down as follows:
Basic modules impart basic, interdisciplinary, technological knowledge.
Technology modules address the important topics of open and closed-loop control technology.
Function modules explain the fundamental functions of automated systems.
Application modules enable training and further education that is aligned to real-life practice.

The technology modules deal with various technologies including pneumatics, electro-pneumatics, programmable logic controllers, automation using a personal computer, hydraulics, electro-hydraulics, proportional hydraulics and applications technology (handling).

The modular design of the training system makes it possible to focus on applications above and beyond those covered in the individual modules, such as, for example, PLC actuation of pneumatic, hydraulic and electric drives.

All training modules have the same structure:

- Hardware
- Courseware
- Software
- Seminars

The hardware is comprised of industrial components and systems that are specially designed for training purposes.
The structure of the courseware corresponds to that of the training hardware. It includes:

- Textbooks (with exercises and examples)
- Workbooks (with practical exercises, supplementary instructions and solutions)
- Transparencies and videos (for dynamic instruction)

The working materials for TP201 consist of 19 exercises and a workbook. Each exercise has its own set of ready-to-use worksheets. The solutions are included in the workbook, which also has the worksheets and a CD ROM. The exercises can be purchased without the workbook and are used as consumables. They can thus be easily made available to trainees. Data sheets for the hardware components are made available along with the training module and on the CD ROM.

The teaching and learning media are available in several languages. They’re intended for use in classroom instruction, but are also suitable for self-study.

Where software is concerned, computer training programs and programming software are made available for programmable logic controllers.

A wide range of seminars covering the contents of the technology module round off the programme for training and further education.

Introduction

This workbook is part of the training system for automation and technology from Festo Didactic GmbH & Co. KG. The system provides a solid basis for practical training and further education. The TP200 technology module only includes electro-pneumatic control systems.

The TP201 basic level is suitable for basic training in the field of electro-pneumatic control technology. It covers the fundamentals of electro-pneumatics as well as the function and use of electro-pneumatic equipment. Simple electro-pneumatic control systems can be set up with the equipment set.

The TP202 advanced level is targeted at vocational training in the field of electro-pneumatic control technology. The two equipment sets can be used to set up extensive combinatory circuits with linking of the input and output signals, as well as programme control systems.

A permanent workstation equipped with a Festo Didactic profile plate is a prerequisite for setting up the control systems. The profile plate has 14 parallel T-slots at 50 mm intervals. A power supply with short-circuit protection is used as a direct voltage source (input: 230 V, 50 Hz, output: 24 V, max. 5 A). A portable compressor with silencer (230 V, max. 8 bar = 800 kPa) can be used for compressed air supply.

Working pressure should not exceed 6 bar (600 kPa).

Ideal reliability can be achieved by operating the control system at a working pressure of 5 bar (500 kPa) without oil.

All the control systems for the 12 exercises are set up using the equipment set for the TP201 basic level. The theoretical fundamentals for understanding this collection of exercises are included in the textbook:

- Electro-pneumatics

Data sheets for the individual components are also available (cylinders, valves, measuring instruments etc.).

Safety precautions and work instructions

General

Trainees should only work with the control systems under the supervision of a trainer.
Observe specifications included in the data sheets for the individual components and in particular all safety instructions!

Mechanical

- Mount all of the components securely onto the profile plate.
- Limit switches may not be actuated frontally.
- Danger of injury during troubleshooting!
- Use a tool to actuate the limit switches, for example a screwdriver.
- Only reach into the set-up when it's at a complete standstill.

Electrical

- Electrical connections must only be established and interrupted in the absence of voltage!
- Use connector cables with safety plugs only for electrical connections.
- Use low-voltage only (max. 24 V DC).

Pneumatics

- Do not exceed the maximum permissible pressure of 6 bar (600 kPa).
- Do not switch on the compressed air until all the tubing connections have been completed and secured.
- Do not disconnect tubing while under pressure.
- Danger of injury when switching compressed air on!
  Cylinders may advance and retract automatically.
- Danger of accident due to tubing slipping off!
  Use shortest possible tubing connections.
  Wear safety glasses.
  In the event that tubing slips off:
  Switch compressed air supply off immediately.
- Pneumatic circuit set-up:
  Connect the components using plastic tubing with an outside diameter of 4 or 6 mm. Push the tubing into the push-in connector as far as it will go.
  Switch compressed air supply off before dismantling the circuit.
- Dismantling pneumatic circuits:
  Press the blue release ring down, after which the tubing can be pulled out.

The mounting boards for the components are equipped with mounting variants A through D:

Variant A, snap-in system
Lightweight components that are not load-bearing (e.g. directional control valves). Simply clip the component into the slot on the profile plate. Release the component from the slot by actuating the blue lever.

Variant B, bolt system
Components with medium load capacity (e.g. drives). These components are clamped to the profile plate using T-head bolts. The blue, knurled nut is used for clamping and loosening.

Variant C, screw system
For components with high load capacity and components which are seldom removed from the profile plate (for example on-off valve with filter regulator). These components are secured with socket head screws and T-head bolts.

Variant D, plug-in system
Lightweight components with locking pins that are not load-bearing (e.g. indicators). These are secured using plug adapters.

Observe specifications in the data sheets regarding the individual components.

Technology module for electro-pneumatics (TP200)

The TP200 technology packet consists of a multitude of training materials and seminars. The subject matter is entirely focused on electro-pneumatic control systems. Individual components included in the TP200 technology module can also be included in any of the other modules.

Important elements of the TP200:

- Permanent workstation with Festo Didactic profile plate
- Compressor (230 V, 0.55 kW, max. 8 bar = 800 kPa)
- Equipment sets or individual components
- Optional training materials
- Practical training models
- Complete laboratory set-ups

Training documentation	
Textbooks	TP201 basic level Fundamentals of pneumatic control technology Maintenance of pneumatic equipment and systems
Workbooks	TP201 basic level TP202 advanced level
Optional courseware	Set of transparencies and overhead projector Magnetic symbols, drawing template Electro-pneumatics WBT, pneumatics WBT Electrical engineering WBTs 1 and 2, electronics WBTs 1 and 2 Set of cutaway models with storage case FluidSIM® pneumatic simulation software

Seminars	
P100	Basic pneumatics knowledge for machine operators
P111	Fundamentals of pneumatics and electro-pneumatics
P121	Maintenance and troubleshooting for pneumatic and electro-pneumatic systems
P-OP	Tracking down waste – economic use of pneumatics
P-NEU	Pneumatics refresher and update
IW-PEP	Repair and maintenance in the field of control technology – pneumatic and electro-pneumatic systems
P-AL	Pneumatics for further education
P-AZUBI	Pneumatics and electro-pneumatics for trainees

Please refer to the current seminar planner for locations, dates and prices.

You'll find further training materials in our catalogue and on the Internet. The training system for automation and technology is continuously updated and expanded. Transparencies, videos, CD ROMs and DVDs, as well as textbooks, are offered in several languages.

Learning objectives for the basic level (TP201)

- Become familiar with the set-up and mode of operation of a single-acting cylinder.
- Become familiar with the set-up and mode of operation of a double-acting cylinder.
- Be able to calculate piston forces based on specified values.
- Become familiar with the set-up and mode of operation of a 3/2-way solenoid valve.
- Become familiar with the set-up and mode of operation of a double solenoid valve.
- Be able to select solenoid valves based on the specified requirements.
- Be able to recognise and sketch the various types of actuation for directional control valves.
- Be able to convert solenoid valves.
- Be able to explain and set up direct actuation.
- Be able to explain and set up indirect actuation.
- Become familiar with logic operations and be able to set them up.
- Become familiar with various types of end-position control and learn to select the appropriate type.
- Be able to calculate characteristic electrical values.
- Become familiar with latching circuits with varying performance features.
- Be able to explain and set up an electrical latching circuit with dominant shutdown signal.
- Be able to set up a pressure-dependent control system.
- Become familiar with the set-up and mode of operation of magnetic proximity switches.
- Become familiar with displacement-step diagrams and learn to create them for specific problems.
- Be able to implement sequence control with two cylinders.
- Be able to detect and eliminate errors in simple electro-pneumatic control systems.

Overview of learning objectives per exercise

Exercise / Learning objectives	1	2	3	4	5	6	7	8	9	10	11	12
Become familiar with the set-up and mode of operation of a single-acting cylinder.	●											
Become familiar with the set-up and mode of operation of a double-acting cylinder.		●	●		●							
Learn to calculate piston forces based on specified values.							●					
Become familiar with the set-up and mode of operation of a 3/2-way valve.	●											
Become familiar with the set-up and mode of operation of a double solenoid valve.					●	●						
Be able to select solenoid valves based on the specified requirements.				●								
Be able to recognise and sketch the various types of actuation for directional control valves.	●											
Be able to convert solenoid valves.				●								
Be able to explain and set up direct actuation.	●	●										
Be able to explain and set up indirect actuation.			●	●			●					
Become familiar with various types of end-position control and learn to select the appropriate type.						●			●			
Become familiar with logic operations and be able to set them up.				●			●					
Be able to calculate characteristic electrical values.							●					
Become familiar with latching circuits with varying performance features.								●	●			
Be able to explain and set up an electrical latching circuit with dominant breaking signal.								●				
Be able to set up a pressure-dependent control system.										●		
Become familiar with the set-up and mode of operation of magnetic proximity switches.										●		
Become familiar with displacement-step diagrams and learn to create them for specific problems.											●	
Be able to implement sequence control with two cylinders.											●	
Be able to detect and eliminate errors in simple electro-pneumatic control systems.												●

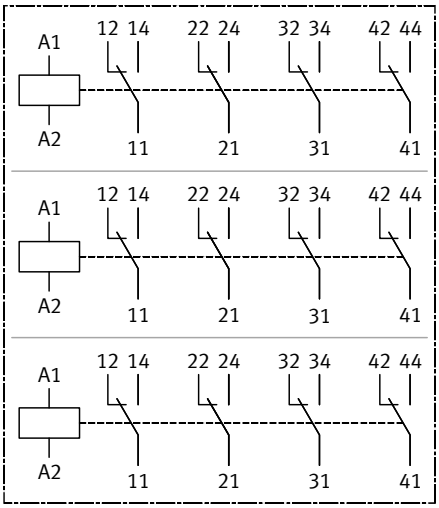
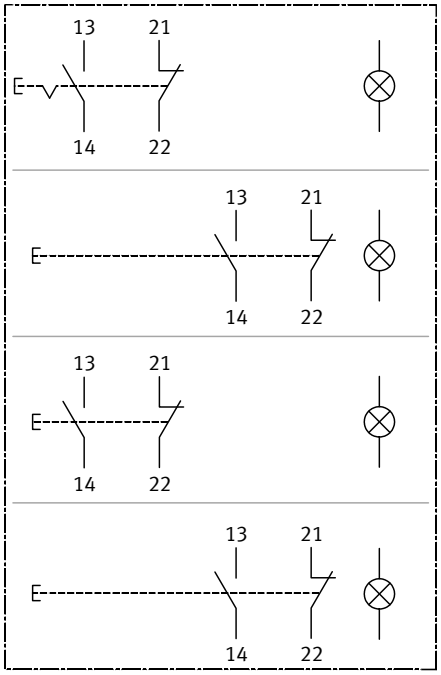
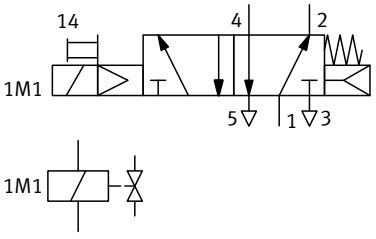
Equipment set for the basic level (TP201)

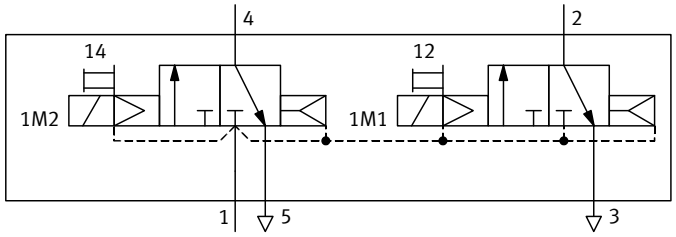
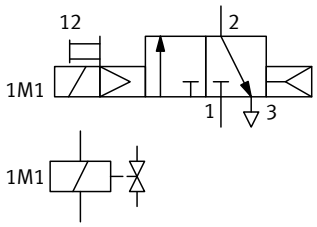
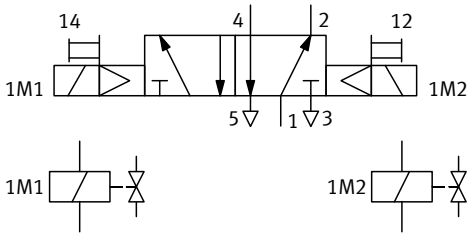
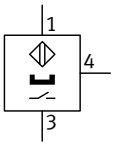
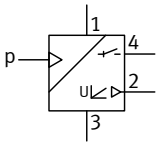
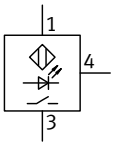
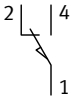
The equipment set has been put together for basic training in the field of electro-pneumatic control technology. It includes all the elements that are necessary for mastering the specific learning objectives and can be supplemented with any other equipment sets. A profile plate, an electrical power supply unit and a source of compressed air are also required in order to set up functional control systems.

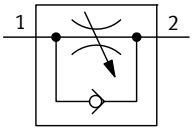
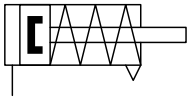
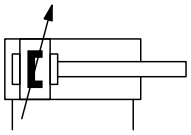
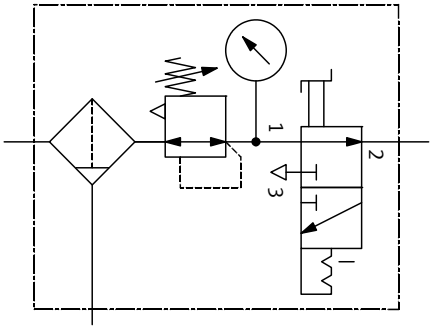
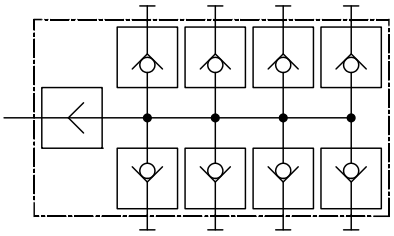
Equipment set for the basic level (TP201)

Designation	Order no.	Quantity
2 x 3/2-way solenoid valve, normally closed	567198	1
5/2-way double solenoid valve	567200	2
5/2-way solenoid valve	567199	1
Blanking plug	153267	10
Double-acting cylinder	152888	2
One-way flow control valve	193967	4
Pressure sensor	572745	1
Single-acting cylinder	152887	1
On-off valve with filter regulator	540691	1
Limit switch, electrical, actuated from left	183322	1
Limit switch, electrical, actuated from right	183345	1
Plastic tubing, 4 x 0.75, 10 m	151496	2
Proximity switch, electronic	540695	2
Proximity switch, optical	572744	1
Relay, 3-way	162241	2
Signal input, electrical	162242	1
Push-in sleeve	153251	10
Push-in T-connector	153128	20
Distributor block	152896	1

Equipment set symbols

Designation	Symbol
Relay, 3-way	
Signal input, electrical	
5/2-way double solenoid valve	

Designation	Symbol
3/2-way solenoid valve, normally closed	Internal design of the valve  Representation in circuits 
5/2-way solenoid valve	
Proximity switch, electronic	
Pressure sensor	
Proximity switch, optical	
Electrical limit switch	

Designation	Symbol
One-way flow control valve	
Single-acting cylinder	
Double-acting cylinder	
On-off valve with filter regulator	
Distributor block	
Connectors	

Allocation of equipment per exercise

Exercise / Components	1	2	3	4	5	6	7	8	9	10	11	12
Cylinder, single-acting	1			1							1	1
Cylinder, double-acting		1	1		1	1	1	1	1	1	1	1
One-way flow control valve	1	2	2	1	2	2	2	2	2	2	3	3
3/2-way solenoid valve, normally closed	1			(1)							1	1
5/2-way solenoid valve		1	1	1				1				
5/2-way double solenoid valve					1	1	1		1	1	1	1
Pressure sensor										1		
Limit switch, electrical						1	2					
Proximity switch, normally open									2	2	1	2
Proximity switch, optical											1	1
Pushbutton, electrical, normally open	1	1	1	2	2	1	1	1	1	1	1	1
Pushbutton, electrical, normally closed								1	1			
Relay			1	1	2	2	3	1	3	3	3	3
Distributor block	1	1	1	1	1	1	1	1	1	1	1	1
On-off valve with filter regulator	1	1	1	1	1	1	1	1	1	1	1	1
Power supply unit, 24 V DC	1	1	1	1	1	1	1	1	1	1	1	1
5/2-way solenoid valve		1	1	1				1				

Practical tools for the trainer

Learning objectives
The basic learning objectives for the exercises in this module are the systematic sketching of circuit diagrams as well as the practical set-up of a control system on the profile plate. This direct interaction involving both theory and practice ensures faster, long-term learning. Each exercise has its own individual learning objectives; the specific learning objectives are documented in the matrix.

Required time
The time required for the exercises depends on the trainee's previous knowledge of the subject matter. For training a skilled labourer in metalworking or electrical installation: approx. 2 weeks. For training a technician or engineer: approx. 1 week.

Equipment sets
The exercises and the equipment sets match each other. For all the exercises you'll only need the components included in the equipment set for the TP201 basic level.
Each exercise in the basic level can be set up on a profile plate.

Structure of the exercises

All 12 exercises in part A have the same structure and are broken down into:

- Title
- Learning objectives
- Presentation of the problem
- Layout
- Parameters
- Project assignment
- Worksheets

The solutions for all the 12 exercises are included in the trainer's manual.

Designations of the components

Pneumatic components are designated in circuit diagrams to DIN ISO 1219 2. All the components included in any given circuit have the same primary identifying number. Letters are assigned depending on each respective type of component. Consecutive numbers are assigned if several components of the same type are included within a single circuit. Pressure lines are designated with a P and are numbered separately.

Drives:	1A1, 2A1, 2A2 ...
Valves:	1V1, 1V2, 1V3, 2V1, 2V2, 3V1 ...
Sensors:	1B1, 1B2 ...
Signal input:	1S1, 1S2 ...
Accessories:	0Z1, 0Z2, 1Z1 ...
Pressure lines:	P1, P2 ...

CD ROM contents

The CD ROM provides you with additional media. The contents of parts A (exercises) and C (solutions) have been saved as PDF files.

The CD ROM has the following structure:

- Operating instructions
- Data sheets
- Demo
- Festo catalogue
- FluidSIM® circuit diagrams
- Industrial applications
- Presentations
- Product information
- Videos

Operating instructions
Operating instructions for various components included in the technology module are available. These instructions are helpful when using and commissioning the equipment.

Data sheets
The data sheets for the components included in the technology module are available as PDF files.

Demo
A demo version of the FluidSIM® pneumatics software package is included on the CD ROM. Even this demo version is suitable for testing control systems developed by the user.

Festo catalogue
The relevant pages from the Festo catalogue will be provided with selected components. The representations and descriptions of the components are intended to demonstrate how the components are presented in an industrial catalogue. Additional information regarding the components is also included.

FluidSIM® circuit diagrams
The FluidSIM® circuit diagrams for all 12 exercises included in the technology module are contained in this directory.

Industrial applications
Photos and graphics representing industrial applications are made available. These can be used to illustrate individual tasks. Project presentations can also be supplemented with these illustrations.

Presentations
Contains short presentations of the components included in the technology module. These can be used, for example, to create project presentations.

Product information

This directory contains product information and data sheets from Festo AG & Co. KG for the components included in this technology module. This is intended to demonstrate which information and data are available for industrial components.

Videos

Several videos of industrial applications complete the media provided with the technology module. Short clips demonstrate the applications in their actual industrial environments.

Equipment set for the advanced level (TP202)

The equipment set for the advanced level has been put together for vocational training in the field of electro-pneumatic control technology. The two equipment sets (TP201 and TP202) include components that are necessary for mastering the predefined learning objectives and can be supplemented as required with other equipment sets from the training system for automation and technology.

Equipment set for the advanced level (TP202, order no. 540713)

Quantity	Designation	Order no.
2	Relay, 3-way	162241
1	Signal input, electrical	162242
1	Time relay, 2-way	162243
1	Preset counter, electrical	1677856
1	Proximity switch, inductive	548643
1	Proximity switch, capacitive	548651
1	Emergency-stop button	183347
1	Valve terminal with 4 valve slices (MMJJ)	540696
2	Non-return valve, piloted	540715

Learning objectives for the advanced level (TP202)

- Describe the structure and application of valve terminals
- Implement sequence controls with overlapping signals – solution according to group method
- Implement sequence controls with overlapping signals – solution with step sequence using spring return valves
- Implement sequence controls with overlapping signals – solution with step sequence using double pilot valve (with control step)
- Describe and set up modes of operation (single/continuous cycle)
- Describe the function and application of a preset counter
- Explain and implement the emergency stop function with spring return valves
- Implement special emergency stop conditions: actuators must come to a standstill during an emergency stop
- Explain function and use of a 5/3-way solenoid valve
- Describe and set up the “Set” operating mode
- Execute troubleshooting in complex electro-pneumatic circuits

Exercise 1: Inspecting beverage cases

Learning objectives

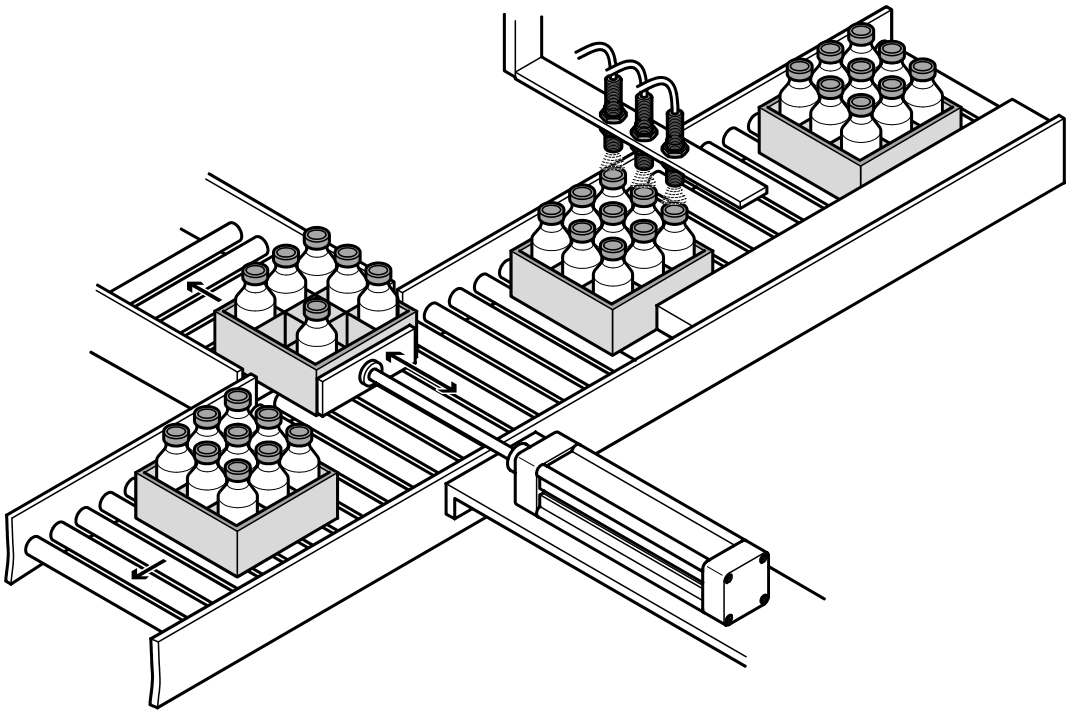
After completing this exercise:

- You'll be familiar with the set-up and mode of operation of a single-acting cylinder.
- You'll be familiar with the set-up and mode of operation of a 3/2-way solenoid valve.
- You'll be able to recognise and sketch the various types of actuation for directional control valves.
- You'll be able to explain and set up direct actuation.

Presentation of the problem

Beverage cases are inspected for completeness with a test device. Incomplete cases are pushed off of the roller conveyor by pressing a pushbutton. Develop a control system with which this process can be executed.

Layout



Test device

Parameters

- A single-acting cylinder is to be used.
- The cylinder will be actuated using a pushbutton.
- In the event of a power failure, the cylinder's piston rod should move to the retracted end position.

Control sequence

1 After pressing a pushbutton, the piston rod of a single-acting cylinder pushes the beverage case from the conveyor.
2 When the pushbutton is released, the piston rod moves to its retracted end position.

Project assignment

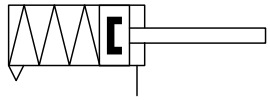
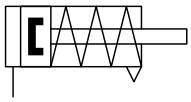
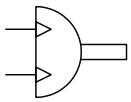
1 Answer the questions and complete the tasks for the learning topics.
2 Draw the pneumatic and electrical circuit diagrams.
3 Create an equipment list.
4 Set up the pneumatic and electrical circuits.
5 Check the circuit sequence.

Function of pneumatic power components

Pneumatic power components can be subdivided into two groups:

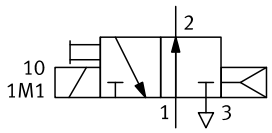
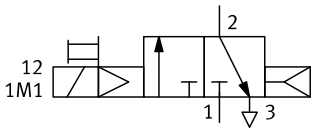
- Power components with straight motion
- Power components with rotary motion

– Describe the power components shown below, as well as their functions.

Symbol	Function
	Single-acting cylinder, reset spring in piston chamber, return stroke by means of compressed air, forward stroke by means of reset spring. **Function** The piston rod of this single-acting cylinder moves to its retracted end position by activating the compressed air. After deactivating the compressed air, the piston moves to its advanced end position by a reset spring in the piston chamber (2 operating positions).
	Single-acting cylinder, reset spring in piston chamber, forward stroke by means of compressed air, return stroke by means of reset spring. **Function** The piston rod of the single-acting cylinder moves to its advanced end position when the compressed air has been activated. After deactivating the compressed air, the piston moves to its retracted end position by a reset spring (2 operating positions).
	Pneumatic quarter turn actuator (rotary drive) with limited swivel angle **Function** This swivel cylinder is double-acting and reverses by alternately activating the compressed air at either end (2 operating positions).

Complete the symbols for solenoid valves

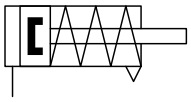
– Complete the individual symbols with the help of the descriptions of the respective components.

Description	Symbol
Directly actuated 3/2-way solenoid valve, normally open, with manual override	
Pilot actuated 3/2-way solenoid valve, normally closed, with manual override	

Normal positions of directional control valves

An electrically actuated 3/2-way solenoid valve has two switching positions. It can be in the normal position (unactuated) or the switched position (actuated). The valve can be either closed or open in its normal position. The single-acting cylinder depicted below is controlled by an electrically actuated 3/2-way solenoid valve.

– Describe how the two different normal positions affect the motion sequence of the cylinder shown below:



3/2-way solenoid valve, normally closed	3/2-way solenoid valve, normally open
The solenoid valve used is reversed by applying voltage to the solenoid coil; flow is enabled from supply port 1 to working port 2. After the signal has been stopped, the valve returns to its normal position by a reset spring and supply port 1 is closed, thus stopping flow. If the directional control valve's solenoid coil is de-energised, the cylinder chamber is vented via exhaust port 3 at the directional control valve. The piston rod is retracted. When the solenoid coil is energised, the directional control valve switches and the cylinder chamber is pressurised. The piston rod advances. When the solenoid coil is de-energised, the valve switches back again. The cylinder chamber is exhausted and the piston rod is retracted. The motion sequence is thus as follows: 1A1+ 1A1-.	The solenoid valve used is reversed by applying voltage to the solenoid coil; supply port 1 is closed, thus stopping flow. After stopping the signal, the valve returns to its normal position by a reset spring and flow from supply port 1 to working port 2 is enabled. If the directional control valve's solenoid coil is de-energised, the cylinder chamber is pressurised via the directional control valve. The piston rod is advanced. When the solenoid coil is energised the directional control valve switches and the cylinder chamber is exhausted via exhaust port 3 at the directional control valve. The piston rod is retracted. When the solenoid coil is de-energised, the valve switches back again. The cylinder chamber is pressurised and the piston rod is advanced. The motion sequence is thus as follows: 1A1- 1A1+.

Direct and indirect actuation

An electrically actuated solenoid valve can be directly or indirectly actuated.

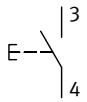
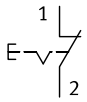
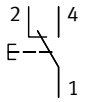
– Describe the difference on the basis of the following example: electrical actuation of a 3/2-way solenoid valve with spring return using a pushbutton.

Direct actuation	Indirect actuation
When the pushbutton is activated, current flows through the valve's solenoid coil. The solenoid is energised and the valve switches to the actuated position. The flow of electrical current is interrupted when the pushbutton is released. The solenoid is de-energised and the valve switches to the normal position.	In the case of indirect actuation, current flows through a relay coil when a pushbutton is activated. The relay's contacts are closed and the valve switches. The valve remains in this switching position as long as electrical current flows through the solenoid coil or the relay coil. The relay drops out when the flow of electrical current through the relay coil is interrupted and the valve switches to its normal position. More complicated indirect actuation is used when the control circuit and the primary circuit use different voltages, when current flowing through the directional control valve's solenoid coil is greater than permissible current for the pushbutton, when several valves are switched with a single pushbutton or pressure switch or if extensive logic operations are required amongst the signals from various pushbuttons.

Design and function of electrical switches

In principle, switches are subdivided into two types, namely pushbuttons and control switches and function as NC contacts, NO contacts or change-over contacts.

– Describe the design and function of the switches depicted below.

Symbol	Design / function
	**Design:** Pushbutton with normally open contacts **Function:** In the case of a pushbutton, the selected switching position is only retained as long as the pushbutton is activated. The pushbutton shown here has a normally open function. With normally open contacts, the electrical circuit is interrupted when the pushbutton is in its normal position, i.e. in the unactivated state. When the control stem is actuated, the electrical circuit is closed and current flows to the consuming device. When the control stem is released, the pushbutton is returned to its normal position by means of spring force and the electrical circuit is interrupted.
	**Design:** Control switch with normally closed contacts **Function:** Control switches are mechanically locked into the two switching positions. The respective switching position is retained until the switch is once again activated. The control switch shown here has a normally closed function. In the case of normally closed contacts, the electrical circuit is closed when the control switch is held in its normal position by means of spring force. When the control switch is activated, the electrical circuit is interrupted and reactivation closes the circuit again.
	**Design:** Pushbutton with change-over contacts **Function:** In the case of a pushbutton, the selected switching position is only retained as long as the pushbutton is activated. The pushbutton shown here has a change-over function. In the case of change-over contacts, NC and NO functions are combined into a single component. An electrical circuit is closed and another is interrupted with a single switching operation. Both circuits are briefly interrupted during switching.

Mode of operation of various valve types

Electrically actuated directional control valves are switched by means of solenoids. In principle, they can be subdivided into two groups:

- Solenoid valves with spring return
- Double solenoid valves

– Explain the difference between the two groups with regard to function and performance in the event of a power failure.

Valve type	Mode of operation
Solenoid valve with spring return	The actuated switching position is only retained as long as electrical current flows through the solenoid coil. The normal position is clearly defined by the reset spring. If there is no electrical power, the valve returns to its normal position by the spring. This may cause dangerous machine motion. For example, the piston rod of a pneumatic cylinder could be returned to its normal position, thus releasing a previously clamped workpiece.
Double solenoid valve	Only a brief signal is required in order to reverse the valve and the last switching position is retained even in the de-energised state as the result of static friction. All solenoid coils are de-energised in the normal position and the normal position cannot be clearly defined. The valve stays in its last switching position in the event of a power failure. No dangerous machine motion can be triggered as a result. For example, the piston rod of a pneumatic cylinder is kept in its operating position and workpiece clamping is thus retained.

Identifying valve ports

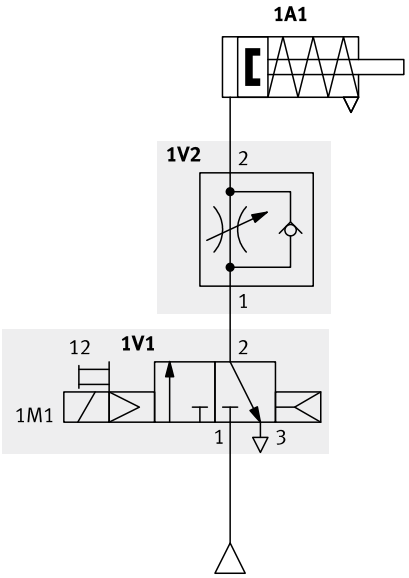
In order to prevent incorrect tubing connections at directional control valves, the valve ports (working and pilot lines) are identified in accordance with ISO 5599-3 on the valves themselves, as well as in the circuit diagram.

– Explain the meanings and functions of the port designations listed below.

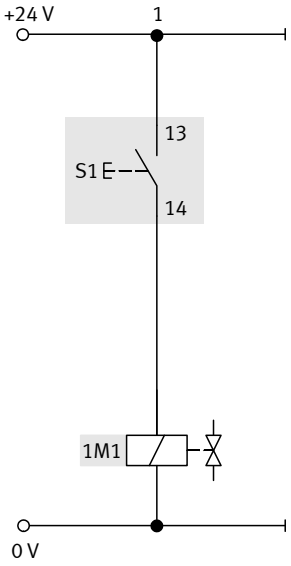
Port identification	Meaning and function
3	Exhaust port
12	Pilot line, function for pilot actuated or pneumatically actuated directional control valves when actuated: supply port 1 and working port 2 are connected
10	Pilot line, function for pilot actuated or pneumatically actuated directional control valves when actuated: supply port 1 is closed

Complete the pneumatic and electrical circuit diagrams

– Complete the pneumatic and electrical circuit diagrams for the sorting system.



Pneumatic circuit diagram



Electrical circuit diagram

Create an equipment list

In addition to the circuit diagram, complete project documentation also includes an equipment list.

– Create an equipment list by entering the required components in the table below.

Quantity	Designation
1	Cylinder, single-acting
1	One-way flow control valve
1	3/2-way solenoid valve, normally closed
1	Pushbutton (normally open)
1	Distributor block
1	On-off valve with filter regulator
1	Compressed air source
1	Power supply unit, 24 V DC

Equipment list

Table of Contents

Exercises and worksheets

Exercise 1: Inspecting beverage cases

Learning objectives

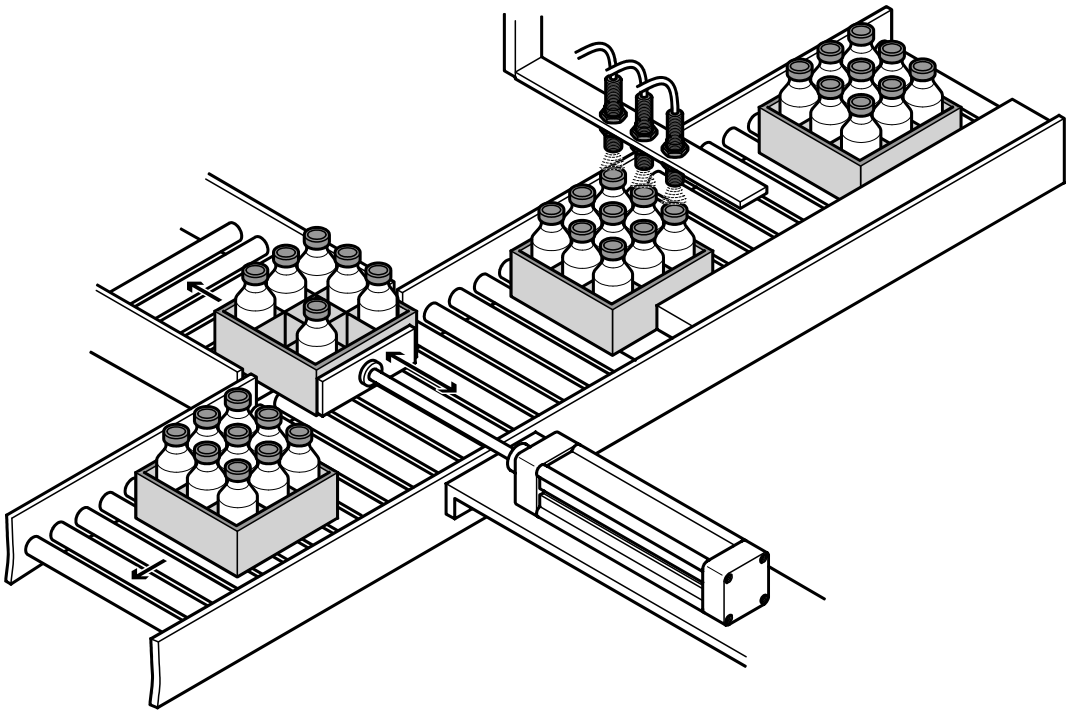
After completing this exercise:

- You'll be familiar with the set-up and mode of operation of a single-acting cylinder.
- You'll be familiar with the set-up and mode of operation of a 3/2-way solenoid valve.
- You'll be able to recognise and sketch the various types of actuation for directional control valves.
- You'll be able to explain and set up direct actuation.

Presentation of the problem

Beverage cases are inspected for completeness with a test device. Incomplete cases are pushed off of the roller conveyor by pressing a pushbutton. Develop a control system with which this process can be executed.

Layout



Test device

Parameters

- A single-acting cylinder is to be used.
- The cylinder will be actuated using a pushbutton.
- In the event of a power failure, the cylinder's piston rod should move to the retracted end position.

Control sequence

1 After pressing a pushbutton, the piston rod of a single-acting cylinder pushes the beverage case from the conveyor.
2 When the pushbutton is released, the piston rod moves to its retracted end position.

Project assignment

1 Answer the questions and complete the tasks for the learning topics.
2 Draw the pneumatic and electrical circuit diagrams.
3 Create an equipment list.
4 Set up the pneumatic and electrical circuits.
5 Check the circuit sequence.

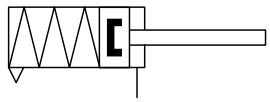
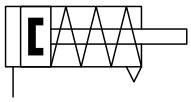
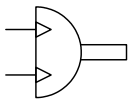
 Name: _____ Date: _____

Function of pneumatic power components

Pneumatic power components can be subdivided into two groups:

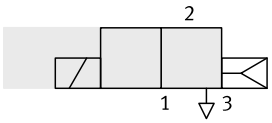
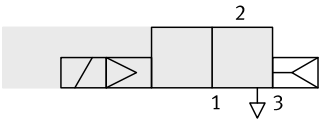
- Power components with straight motion
- Power components with rotary motion

– Describe the power components shown below, as well as their functions.

Symbol	Function
	
	
	

Complete the symbols for solenoid valves

– Complete the individual symbols with the help of the descriptions of the respective components.

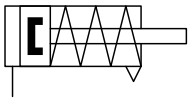
Description	Symbol
Directly actuated 3/2-way solenoid valve, normally open, with manual override, spring return	
Pilot actuated 3/2-way solenoid valve, normally closed, with manual override, spring return	

 Name: _____ Date: _____

Normal positions of directional control valves

An electrically actuated 3/2-way solenoid valve has two switching positions. It can be in the normal position (unactuated) or the switched position (actuated). The valve can be either closed or open in its normal position. The single-acting cylinder depicted below is controlled by an electrically actuated 3/2-way solenoid valve.

– Describe how the two different normal positions affect the motion sequence of the cylinder shown below:



3/2-way solenoid valve, normally closed	3/2-way solenoid valve, normally open

Direct and indirect actuation

An electrically actuated solenoid valve can be directly or indirectly actuated.

– Describe the difference on the basis of the following example: electrical actuation of a 3/2-way solenoid valve with spring return using a pushbutton.

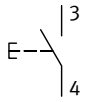
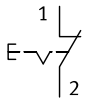
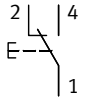
Direct actuation	Indirect actuation

 Name: _____ Date: _____

Design and function of electrical switches

In principle, switches are subdivided into two types, namely pushbuttons and control switches and function as NC contacts, NO contacts or change-over contacts.

– Describe the design and function of the switches depicted below.

Symbol	Design / function
	**Design:** **Function:**
	**Design:** **Function:**
	**Design:** **Function:**

Mode of operation of various valve types

Electrically actuated directional control valves are switched by means of solenoids. In principle, they can be subdivided into two groups:

- Solenoid valves with spring return
- Double solenoid valves

– Explain the difference between the two groups with regard to function and performance in the event of a power failure.

Valve type	Mode of operation
Solenoid valve with spring return	
Double solenoid valve	

Identifying valve ports

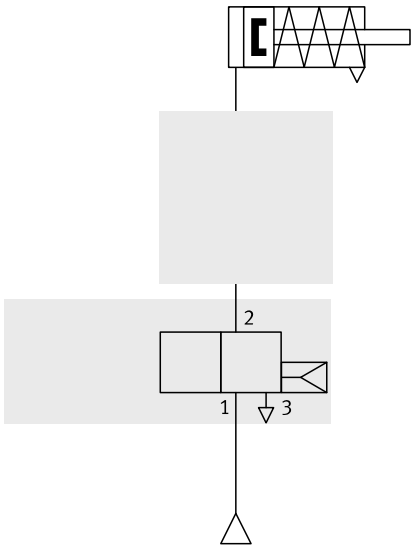
In order to prevent incorrect tubing connections at directional control valves, the valve ports (working and pilot lines) are identified in accordance with ISO 5599-3 on the valves themselves, as well as in the circuit diagram.

– Explain the meanings and functions of the port designations listed below.

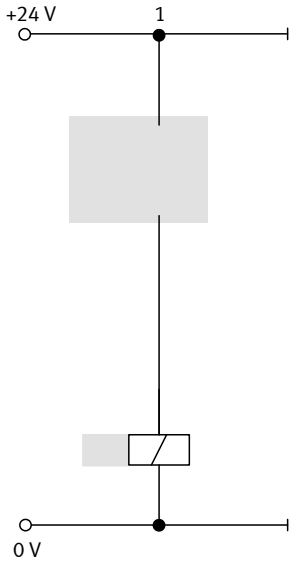
Port identification	Meaning and function
3	
12	
10	

Complete the pneumatic and electrical circuit diagrams

– Complete the pneumatic and electrical circuit diagrams for the sorting system.



Pneumatic circuit diagram



Electrical circuit diagram

Create an equipment list

In addition to the circuit diagram, complete project documentation also includes an equipment list.

– Create an equipment list by entering the required components in the table below.

Quantity	Designation

Equipment list

