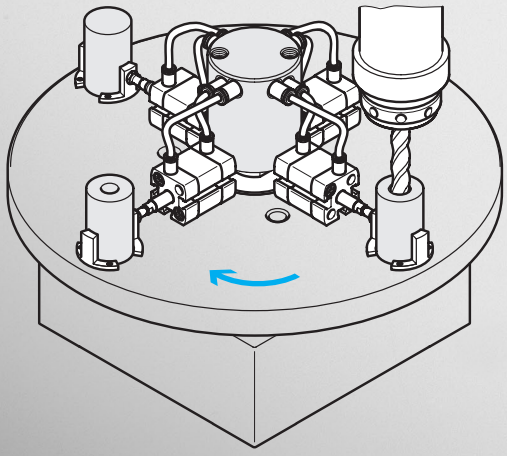
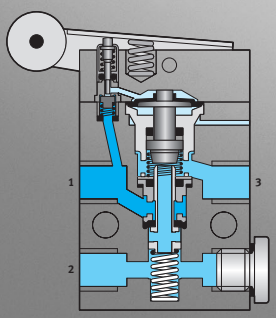
Pneumatics
Basic level

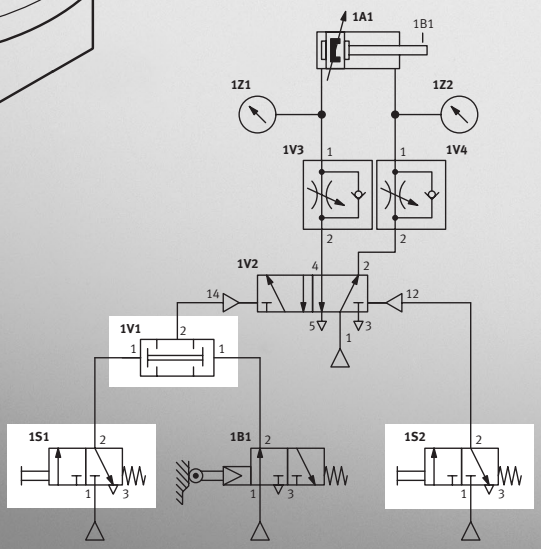
FESTO

Workbook
TP 101

With CD-ROM







Festo Didactic
541088 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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Solutions

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 with real-life practice.

The technology modules deal with various technologies including pneumatics, electro-pneumatics, programmable logic control systems, automation using a personal computer, hydraulics, electrohydraulics, proportional hydraulics, sensor technology, electric drives 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
- Teachware
- Software
- Seminars

The hardware is comprised of industrial components and systems that are specially designed for training purposes.

The structure of the teachware 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 TP101 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 TP100 technology module only includes pneumatic control systems.

The TP101 basic level is suitable for basic training in the field of pneumatic control technology. It covers the fundamentals of pneumatics as well as the function and use of pneumatic equipment. The equipment can be used to set up simple pneumatic control systems.

The TP102 advanced level comprises vocational training in the field of pneumatic control technology. The equipment can be used to set up extensive combinatory circuits with linking of the input and output signals as well as control systems with stepper modules.

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 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 control sequence 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 19 exercises are set up using the equipment set for the TP101 basic level. The theoretical fundamentals for understanding this series of exercises are included in the textbook:

- Pneumatics, basic level

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

Work instructions and safety precautions

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 the components securely onto the profile plate.
- Limit switches must 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!
- Only use connector cables with safety plugs for electrical connections.
- Only use low-voltage (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 of 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 the pneumatic circuit:
  Press the blue release ring down, after which the tubing can be pulled out.

The mounting boards for the components are equipped with mounting variant A, B or C:

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

Variant B, bolt-on system
Components with medium load capacity (e.g. actuators). These are clamped onto 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 that 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.

Observe specifications in the data sheets regarding the individual components.

A stopwatch is required in order to evaluate the control systems once they have been set up. The stopwatch is used to:

- Adjust the one-way flow control valves so that the cylinder stroke times comply with the specified values
- Adjust time delay valves

Technology module for pneumatics (TP100)

The TP100 technology module consists of a multitude of training materials and seminars. The subject matter is focused entirely on pneumatic control systems. Individual components included in the TP100 technology packet can also be included in any of the other modules.

Important components of the TP100

- Permanent workstation with Festo Didactic profile plate
- Compressor (230 V, 0.55 kW, max. 8 bar = 800 kPa)
- Equipment sets or individual components (e.g. cylinders, directional control valves, preset counters, stepper modules, logic components, pneumatic proximity switches)
- Optional training materials (e.g. optical displays, 5/3-way valve, pulling/pushing load)
- Practical training models
- Complete laboratory set-ups

Training documentation	
Textbooks	TP101 basic level Fundamentals of pneumatic control technology Maintenance of pneumatic equipment and systems Pneumatics/electropneumatics
Workbooks	TP101 basic level TP102 advanced level
Optional teachware	Set of transparencies Magnetic symbols, drawing template FluidSIM® pneumatic simulation software WBT Pneumatics Set of cutaway models with storage case

Seminars	
P100	Basic pneumatics for machine operators
P111	Fundamentals of pneumatics and electropneumatics
P121	Maintenance and troubleshooting for pneumatic and electropneumatic systems
P-OP	Tracking down wastage – economic use of pneumatics
P-NEU	Pneumatic refresher and update
IW-PEP	Repair and maintenance in the field of control technology – pneumatic and electropneumatic systems
P-AL	Pneumatics for further education
P-AZUBI	Pneumatics and electropneumatics 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 (TP101)

- 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 3/2-way valve.
- Be able to recognise and sketch the various types of actuation for directional control valves.
- Be able to explain and set up direct actuation.
- Be able to analyse and evaluate circuits.
- Become familiar with the set-up and mode of operation of a double-acting cylinder.
- Become familiar with the set-up and mode of operation of a 5/2-way valve.
- Be able to explain and set up indirect actuation.
- Become familiar with the mode of operation of a 5/2-way valve with pneumatic actuation.
- Become familiar with the difference between a signalling element and a control element.
- Be able to measure pressure in pneumatic control systems.
- Be able to differentiate between the various types of flow control and use them in accordance with specifications.
- Be able to adjust cylinder advancing and retracting speeds.
- Become familiar with one type of signal storage in pneumatic control systems.
- Be able to explain and implement AND/OR/NOT logic operations.
- Be able to explain and set up latching circuits.
- Become familiar with one option for end-position sensing in cylinders.
- Be able to combine logic operations.
- Become familiar with the set-up and mode of operation of a magnetic proximity switch.
- Be able to differentiate between 5/2-way valves and to select and use them in accordance with specifications.
- Be able to further develop existing circuits.
- Become familiar with the set-up and mode of operation of a pressure sequence valve.
- Be able to set up pressure-dependent control systems.
- Become familiar with the set-up and mode of operation of a pressure regulator.
- Be able to analyse existing circuits and optimise them in accordance with specifications.
- Become familiar with the set-up and mode of operation of a time delay valve.
- Be able to set up circuits with oscillating motion.
- Be able to use time delay valves in accordance with specific constraints.
- Be able to analyse and set up circuits with two cylinders.

Overview of learning objectives per exercise

Exercise / Learning Objective	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
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 3/2-way valve.	•	•	•																
Be able to recognise and sketch the various types of actuation for directional control valves.	•	•	•																
Be able to explain and set up direct actuation.	•	•	•	•															
Be able to analyse and evaluate circuits.			•													•			
Become familiar with the set-up and mode of operation of a double-acting cylinder.				•															
Become familiar with the set-up and mode of operation of a 5/2-way valve.				•	•														
Be able to explain and set up indirect actuation.					•					•									
Become familiar with the difference between a signalling element and a control element.					•														
Be able to measure pressure in pneumatic control systems.						•													
Be able to differentiate between the various types of flow control and use them in accordance with specifications.						•	•												
Be able to adjust cylinder advancing and retracting speeds.							•	•											

Exercise / Learning Objective	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Become familiar with one type of signal storage in pneumatic control systems.								•											
Be able to explain and implement AND/OR/NOT logic operations.									•	•	•	•	•						
Be able to explain and set up latching circuits.										•									
Become familiar with one option for end-position sensing in cylinders.											•								
Be able to combine logic operations.												•	•						
Become familiar with the set-up and mode of operation of a magnetic proximity switch.												•							
Be able to differentiate between 5/2-way valves and to select and use them in accordance with specifications.												•							
Be able to further develop existing circuits.									•				•						
Become familiar with the set-up and mode of operation of a pressure sequence valve.														•					
Be able to set up pressure-dependent control systems.														•	•	•	•		
Become familiar with the set-up and mode of operation of a pressure regulator.															•				
Become familiar with the set-up and mode of operation of a time delay valve.																	•		
Be able to set up circuits with oscillating motion.																		•	
Be able to use time delay valves in accordance with specific constraints.																		•	
Be able to analyse and set up circuits with two cylinders.																			•

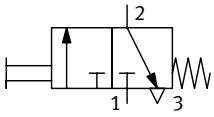
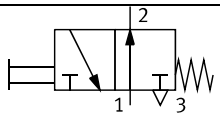
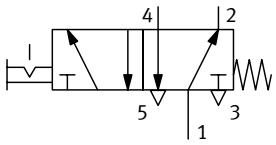
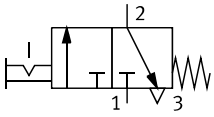
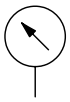
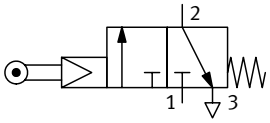
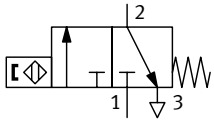
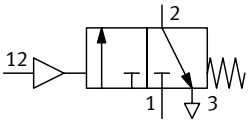
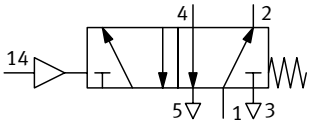
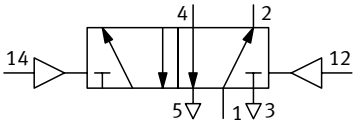
Equipment set for the basic level (TP101)

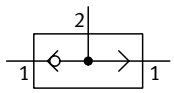
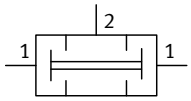
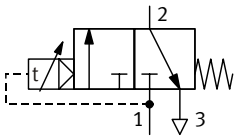
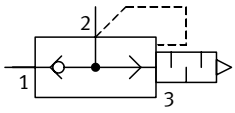
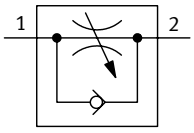
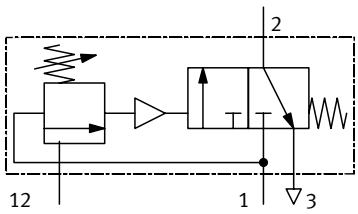
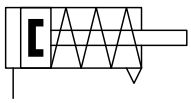
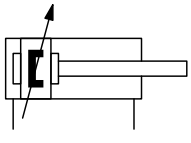
The equipment set has been put together for basic training in the field of pneumatic control technology. It includes all the components that are necessary for mastering the specific learning objectives and can be supplemented with any other equipment sets. A profile plate and a source of compressed air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

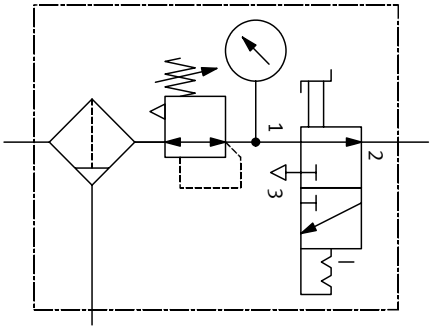
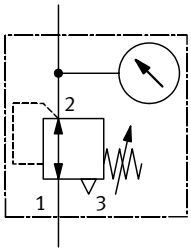
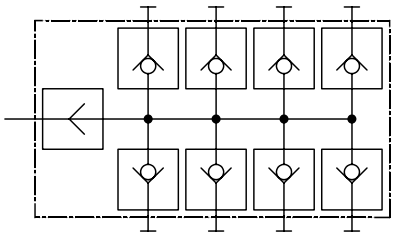
Equipment set for the basic level (TP101)

Quantity	Designation	Order no.
2	3/2-way roller lever valve, normally closed	152866
1	3/2-way valve with pushbutton, normally open	152861
2	3/2-way valve with pushbutton, normally closed	152860
1	3/2-way valve with selector switch, normally closed	152863
1	3/2-way valve, pneumatically actuated at one end	539768
3	5/2-way double pilot valve, pneumatically actuated at both ends	539769
1	5/2-way valve with selector switch	152862
1	5/2-way valve, pneumatically actuated at one end	538694
1	Double-acting cylinder	152888
2	One-way flow control valve	193967
2	Pressure gauge	152865
1	Pressure regulator with pressure gauge	539756
1	Pressure sequence valve	152884
1	Single-acting cylinder	152887
1	On-off valve with filter regulator	540691
2	Plastic tubing, 4 x 0.75, silver, 10 m	151496
2	Pneumatic proximity switch with cylinder mounting	539775
1	Pneumatic timer, normally closed	540694
1	Quick exhaust valve	539772
10	Push-in sleeve	153251
10	Push-in T-connector	153128
1	Distributor block	152896
1	Shuttle valve (OR)	539771
2	Dual-pressure valve (AND)	539770

Equipment set symbols

Designation	Symbol
3/2-way valve with pushbutton, normally closed	
3/2-way valve with pushbutton, normally open	
5/2-way valve with selector switch	
3/2-way valve with selector switch	
Pressure gauge	
3/2-way roller lever valve, normally closed	
Pneumatic proximity switch	
3/2-way valve, pneumatically actuated at one end	
5/2-way valve, pneumatically actuated at one end	
5/2-way double pilot valve, pneumatically actuated at both ends	

Designation	Symbol
Shuttle valve	
Dual-pressure valve	
Pneumatic timer, normally closed	
Quick exhaust valve	
One-way flow control valve	
Pressure sequence valve	
Single-acting cylinder	
Double-acting cylinder	

Designation	Symbol
On-off valve with filter regulator	
Pressure regulator with pressure gauge	
Distributor block	
Connectors	

Allocation of equipment per exercise

Exercise / Equipment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Cylinder, single-acting	1	1	1	1					1										1
Cylinder, double-acting					1	1	1	1		1	1	1	1	1	1	1	1	1	1
One-way flow control valve						2	2	1		2	2	2	2	2	2	2	1	2	2
Quick exhaust valve								1									1		
Pressure gauge						2	2	1			2						1		
3/2-way valve, pushbutton, normally closed	1								2	1	2	2	1	2	2	1	1	1	1
3/2-way valve, pushbutton, normally open		1								1									
3/2-way valve, selector switch, normally closed			1		1			2					1						
3/2-way roller lever valve, normally closed											1							1	1
Pneumatic proximity switch												2	2	2	1	2	2	2	2
3/2-way pneumatic valve										1						1			
3/2-way pneumatic double pilot valve																		1	1
5/2-way valve, selector switch				1		1	1												
5/2-way pneumatic valve					1					1	1	1							
5/2-way pneumatic double pilot valve								1					1	1	1	1	1	1	1
Shuttle valve									1	1		1		1				1	
Dual-pressure valve											1	2	2	1	1	2	1		1
Pressure sequence valve														1	1	1			
Pressure regulator with pressure gauge														1	2	1	1		
Time delay valve, normally closed																	1	1	
Distributor block	1	1	1	1	1	1	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	1	1	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 learner'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 matched each other. For all 19 exercises you'll only need the components included in the equipment set for TP101 basic level.

Each exercise in the basic level can be set up on a profile plate.

Structure of the exercises

All 19 exercises have the same structure and are broken down into:
- Title
- Learning objectives
- Presentation of the problem
- Parameters
- Project assignment
- Layout
- Worksheets

The solutions for all the 19 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.

Cylinders:	1A1, 2A1, 2A2 ...
Valves:	1V1, 1V2, 1V3, 2V1, 2V2, 3V1 ...
Sensors:	1B1, 1B2 ...
Signal inputs:	1S1, 1S2 ...
Accessories:	0Z1, 0Z2, 1Z1 ...

CD ROM contents

The CD ROM provides you with additional media. The worksheets and solutions have been saved as PDF files on the CD ROM that is included with the trainer's manual.

The CD ROM contains the following folders:

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

Operating instructions
Operating instructions for the 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 supplied along with the equipment set and are available as PDF files.

FluidSIM® demo version
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 19 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 for the components included in the 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 (TP102)

The equipment set for the advanced level has been put together for further training in the field of pneumatic control technology. The two equipment sets (TP101 and TP102) 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 (TP102)

Quantity	Designation	Order no.
1	3/2-way roller lever valve with idle return, normally closed	152867
2	3/2-way valve with pushbutton, normally closed	152860
1	3/2-way valve with mushroom actuator (red), normally open	152864
4	3/2-way valve, pneumatically actuated at one end	539768
2	5/2-way double pilot valve, pneumatically actuated at both ends	539769
2	Double-acting cylinder	152888
2	One-way flow control valve	193967
2	Plastic tubing, 4 x 0.75, silver, 10 m	151496
1	Pneumatic timer, normally open	539759
2	Non-return valve, piloted non-return function	540715
1	Back pressure limit valve	152868
10	Push-in sleeve	153251
1	Stepper module	152886
20	Push-in T-connector	153128
1	Pneumatic preset counter	152877
1	Shuttle valve (OR)	539771
1	Shuttle valve, 3-way (OR)	152882
1	Dual-pressure valve, 3-way (AND)	152883

Learning objectives for the advanced level (TP102)

- Detect end-positions without limit switches
- Understand and set up flip-flop circuits (flip-flop, double pilot valve)
- Convert a 3/2 and/or a 5/2-way valve
- Evaluate, use and adjust various sensors
- Explain the function of a back pressure end stop
- Explain the function of stepper modules
- Develop basic sequence control systems (continuous cycle)
- Implement a sequence control system with the following operating modes: automatic/manual, start and reset
- Implement an OR operation for feedback signals
- Set and coordinate delays
- Be able to abort delay times with an OR operation
- Implement a sequence control system with idle step (3 steps)
- Describe and set up variable step repetition within a motion sequence using a preset counter
- Develop an input circuit with self-latching loop including the following functions: automatic/manual, start, stop (at end of cycle) and reset
- Evaluate and use sensors for material sensing
- Actuate the final control element with two steps via a shuttle valve (double cylinder stroke)
- Use a proximity switch within the stroke sub-range in order to reverse cylinder motion
- Development of an input circuit for a sequence control system with secure pilot air, as well as start, emergency stop and reset functions
- Stop the cylinder within the sub-stroke range (positioning) by pressurising at both ends (preloading)
- Adjust proximity switches in the end positions and within the sub-stroke range
- Combined use of quick exhaust valve and pressure regulator with pressure gauge
- Set up an inverted timer signal
- Implement a control system with guide features in combination with sequence control

Exercise 1: Pressing cheeses

Learning objectives

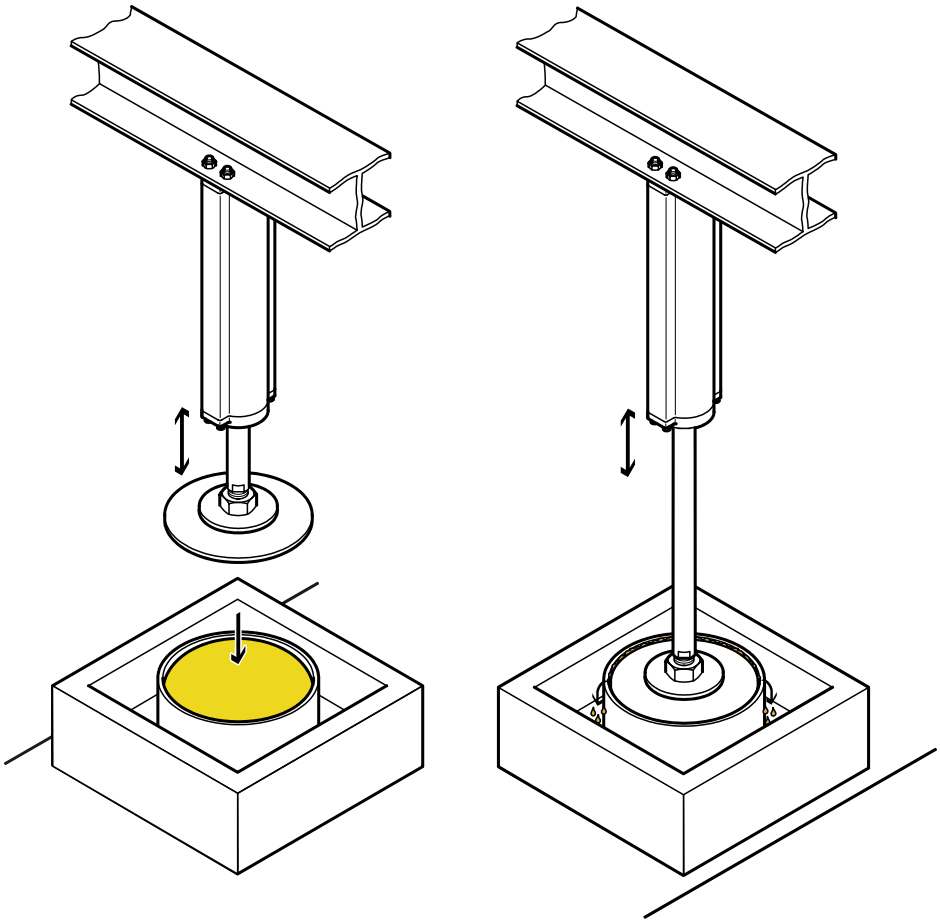
After completing this exercise you'll:

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

Presentation of the problem

Presses are used to press cheeses into moulds during the production process. Develop a control system with which this process can be executed

Layout



Cheese production

Parameters

- Use a double-acting cylinder.
- Pneumatically control the cylinder using a manually actuated valve.

Project assignment

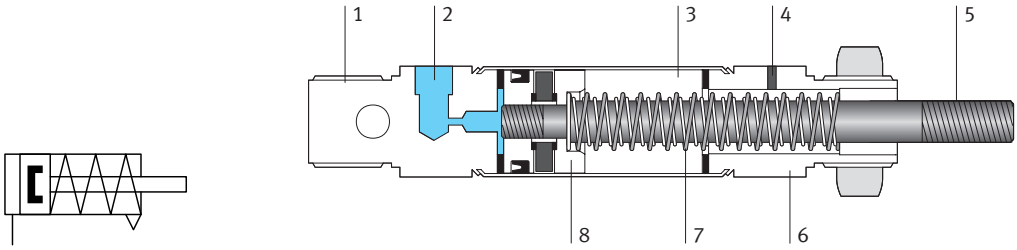
1. Describe the mode of operation of a single-acting cylinder.
2. Describe the mode of operation of a normally closed 3/2-way valve.
3. Complete the pneumatic circuit diagram for the pressing tool.
4. Set up the control system.
5. Double-check the control system configuration.
6. Describe the mode of operation of the control system.
7. Create an equipment list.

Procedure

1. The cheeses are placed into the tool manually.
2. When the pushbutton is activated, the cylinder advances and presses the cover onto the tool.
3. The pushbutton is pressed and held until the pressing operation has been completed.
4. When the pushbutton is released, the cylinder is retracted and the tool can be accessed.
5. The cheese can be removed.

Safety note
Limit pressure at the service unit for this exercise to a maximum of3.5 bar (350 kPa). Immediately deactivate compressed air supply if the tubing slips off.

Set-up and mode of operation of a single-acting cylinder



Circuit symbol and schematic diagram of a single-acting cylinder

– Compare the circuit symbol shown above with the schematic diagram of the single-acting cylinder. Determine whether or not the two representations coincide with each other.

The two representations coincide with each other.

– Describe the set-up and mode of operation of a single-acting cylinder.

The compressed air flows into the cylinder's piston chamber. Pressure is built up in the chamber and force is applied to the surface of the piston as a result. If this force exceeds static friction, the piston is advanced. Pressure is not built up to full operating pressure until the piston is fully advanced.
When this pressure drops, the integrated return spring forces the piston back into its initial position. Spring force is not great enough to move heavy loads attached to the piston rod. Hence single-acting cylinders only perform work in a single direction.

– Match up each component with the corresponding number from the above drawing.

Component	Designation
3	Cylinder barrel
1	End cap
6	Bearing cap
5	Piston rod
8	Piston
7	Spring return
2	Supply port
4	Exhaust port

Table of component designations

Calculate the piston force of a single-acting cylinder

Theoretical piston force is calculated using the following formula:

$F_{th} = A \cdot p$

F_{th} = theoretical piston force (N)

A = effective piston surface (sq. metres)

$= (\frac{D^2 \cdot \pi}{4})$

p = working pressure (Pa)

D = cylinder diameter (m)

Piston force F_{eff} is important in actual practice. Frictional resistance has to be taken into consideration when calculating piston force. Under normal operating conditions (pressure range of 4 to 8 bar or 400 to 800 kPa), it is assumed that friction forces (F_R) amount to roughly 10% of the theoretical piston force.

The following applies to the effective piston force of single-acting cylinders:

$F_{eff} = A \cdot p - (F_R + F_F)$

F_{eff} = effective piston force (N)

F_R = friction force (approx. 10% of F_{th}) (N)

F_F = return spring force (N)

– Calculate the effective piston force for the advance stroke of the used cylinder with a working pressure of 6 bar (600 kPa).

$A = (\frac{0.02^2 \cdot 3.14}{4}) = 0.000314$

$F_{eff} = 0.9 \cdot A \cdot p - F_F$

$F_{eff} = 0.9 \cdot (0.000314) \cdot 600{,}000 - 13.5$

$F_{eff} = 169.56 - 13.6 = 155.96$ N

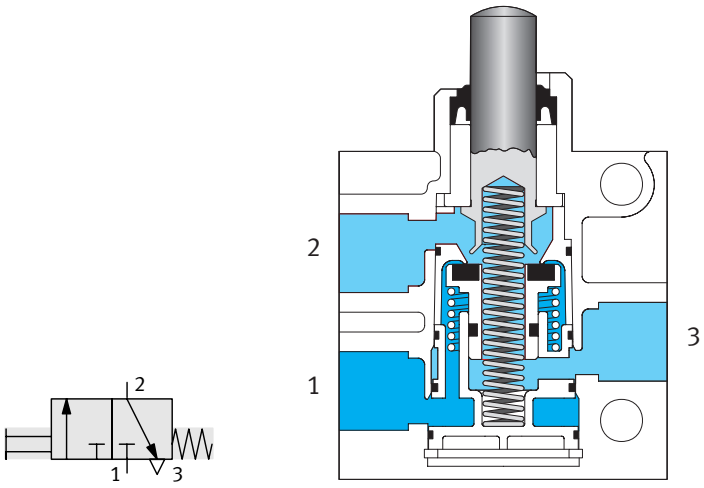
Note

The required data is included in the data sheet for the cylinder.

The piston diameter of the used cylinder is 20 mm and spring return force is 13.6 N.

Mode of operation of a normally closed 3/2-way valve

– Complete the circuit symbol of a manually actuated, normally closed 3/2-way valve with spring return.



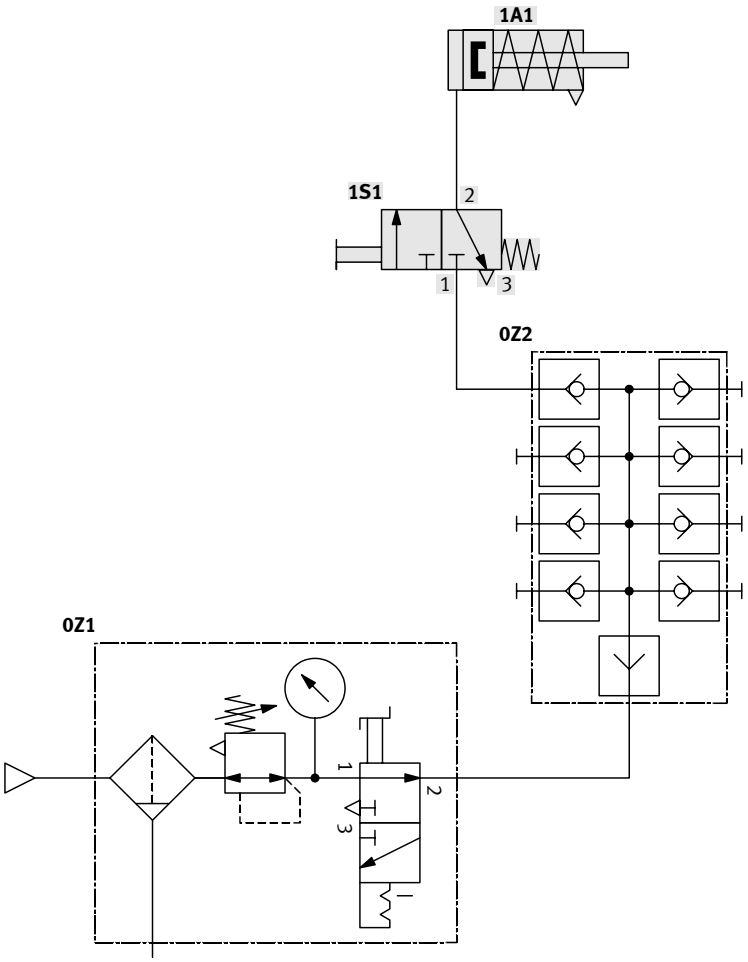
Circuit symbol and schematic representation of a normally closed 3/2-way valve

– Describe the mode of operation of the 3/2-way valve.

A 3/2-way valve has 3 ports and 2 switching positions. It's represented in the normal position. Normally closed means that compressed air cannot flow through the valve. When the pushbutton is actuated the valve is opened, thus allowing air to flow and the piston of a connected cylinder is advanced.

Complete the pneumatic circuit diagram

– Complete the pneumatic circuit diagram for the control system and enter the port designations.



Pneumatic circuit diagram

Sequence description

– Set up the control system and describe its working sequence.

Initial position
Valve 1S1 is closed in its initial position. The piston rod of cylinder 1A1 is retracted.

Step 1-2
When the pushbutton on 3/2-way valve 1S1 is pressed, compressed air flows into the piston chamber of cylinder 1A1 and the piston rod is advanced.

Step 2-3
When the pushbutton is released, valve 1S1 is exhausted and cylinder 1A1 returns to its initial position due to force applied by the return spring.

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 and their quantities in the table below.

Quantity	Designation
1	Cylinder, single-acting
1	3/2-way valve with pushbutton, normally open
1	Distributor block
1	On-off valve with filter regulator
1	Compressed air source

Equipment list