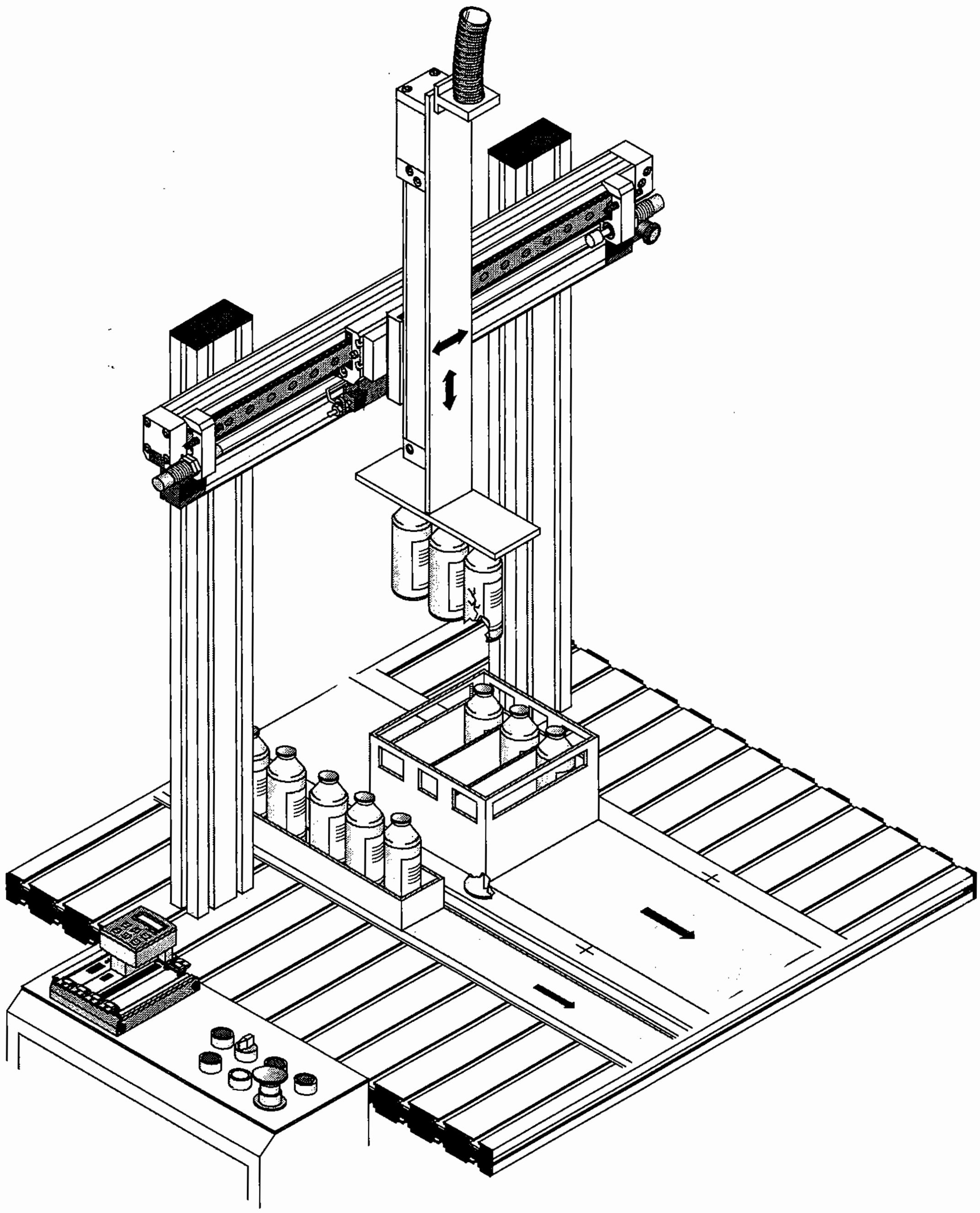
FESTO

Servo-Pneumatic Positioning

Workbook



196949

Order No.:	196949
Description:	WORKBOOK
Designation:	D:LW-PNEUPOS-GB
Edition:	04/2001
Authors:	H.-J. Eberhardt, D. Scholz
Graphics:	Doris Schwarzenberger
Layout:	18.04.2001, Beatrice Huber

Internet: www.festo.com/didactic
e-mail: did@festo.com

Contents

Part B Fundamentals

Preface

The "Servo-Pneumatic Positioning" function package forms part of the learning system for Automation and Technology from Festo Didactic GmbH & Co.

Essentially, the equipment set comprises components compatible with those used for industrial applications. At the same time, the positioning axes are harmonised with the learning system for Automation and Technology.

Industrial application of pneumatic NC axes

The high flexibility, the relatively low-cost set-up and high motion dynamics ensure pneumatic NC axes a constantly increasing area of application.
- Pneumatic NC axes are used, for instance, in robotics or for palletisation tasks.
- One other area of application is software-controlled approach to stops. By comparison with conventional cylinder drives actuated with switching valves, these systems achieve far faster movements and shorter cycle times.

PneuPos 1 - basic equipment set

The PneuPos1 basic equipment set consists of the following components:
- Linear drive (rodless cylinder) with guide and slide
- Festo MPYE-5-1/8 proportional valve
- Displacement measuring system (potentiometer)
- Festo SPC 200 axis controller for open and closed-loop control with related axis interface
- WinPISA PC software
- Electrical and pneumatic accessories
- Workbook with exercises and technical knowledge
- Manual for the WinPISA software

The WinPISA software can run on a personal computer (operating system: Windows or Windows NT).

PneuPos 1 course topics

The basic equipment set serves as an introduction to numerical control systems. The following course topics are taught:
- Setting up and commissioning a servo-pneumatic axis
- Programming numerically controlled axes to DIN 66025
- Examining and optimising the control response
- Self-adapting control algorithms
- EMERGENCY-STOP circuits
- Fault-finding

Another important course topic is using a PC as a programming and optimisation aid. The WinPISA software enables the NC axes to be operated very conveniently and allows graphic visualisation of the motion and control response of pneumatic servo drives.

PneuPos 2 extension equipment set

The PneuPos2 extension equipment set consists of the following components:
- Linear drive (rodless cylinder) with guide and slide and integrated displacement measuring system
- Festo MPYE-5-1/8 proportional valve
- Axis interface
- Columns for setting up a gantry system
- Electrical and pneumatic accessories

PneuPos 2 course topics

The PneuPos2 extension equipment set supports learning of the following course topics:
- Setting up and commissioning a gantry consisting of two pneumatic NC axes
- Programming the gantry to DIN 66025
- Examining and optimising the control response of a vertically mounted axis
- EMERGENCY-STOP: Pneumatic and electrical circuitry, system behaviour
- Fault-finding on multi-axis equipment

Gripper extension equipment set

The "gripper" extension equipment set contains:
- A pneumatically actuated gripper
- A switching valve for actuation
- An interface for connection to the NC control SPC 200
- Electrical and pneumatic accessories

Gripper extension equipment set course topics

The gripper extension equipment set supports the following course topics:
- Programming binary inputs and outputs with the NC axis control SPC200
- Implementing applications in which specific workpieces are moved
- EMERGENCY-STOP behaviour of gripping devices

SPC 10
extension equipment set

The SPC 10 extension equipment set contains:

- The SPC controller (low-cost control for pneumatic high-speed drives)
- Electrical and pneumatic accessories.

SPC 10
extension equipment set
course topics

The SPC 10 extension equipment supports the following course topics:

- Time-optimised positioning of pneumatic cylinders with proportional valve
- Setting up and programming the SPC 10

Equipment/exercise table

Equipment set	Exercises
PneuPos 1	A1 to A6
PneuPos 1 + PneuPos 2	A7 to A10
PneuPos 1 + PneuPos 2 + gripper	A11 to A12
PneuPos 1 + SPC 10	A13

Concept of the workbook

This workbook forms part of the learning system for Automation and Technology from Festo Didactic GmbH & Co.

The workbook is subdivided into the following parts:
Part A: Course
Part B: Fundamentals
Part C: Solutions
Part D: Appendix

Part A, Course, explains how to commission and program servo-pneumatic axes on the basis of exercises which build on each other. The equipment sets required for performing the exercises are shown in the equipment/exercise table.

Part B, Fundamentals, contains generally valid technical knowledge as a supplement to the course topics of the exercises in Part A. It presents the theoretical interrelationships and clearly explains the required technical terms on the basis of examples.

Part C, Solutions, presents the results of the exercises and explains them briefly.

Part D, Appendix, serves as a reference work. It contains Standards and bibliography. The data sheets are enclosed with the equipment used.

The book is structured so that the technical content can be learned both by practical exercises, e.g. in seminars, and by self-study.

Part A

Part A Exercises and worksheets

Exercise 1
Setting up a servo-pneumatic axis

Training aim

- To be able to set up the system mechanically
- To be able to perform wiring and tubing connection
- To be able to prepare the system for commissioning

Technical knowledge

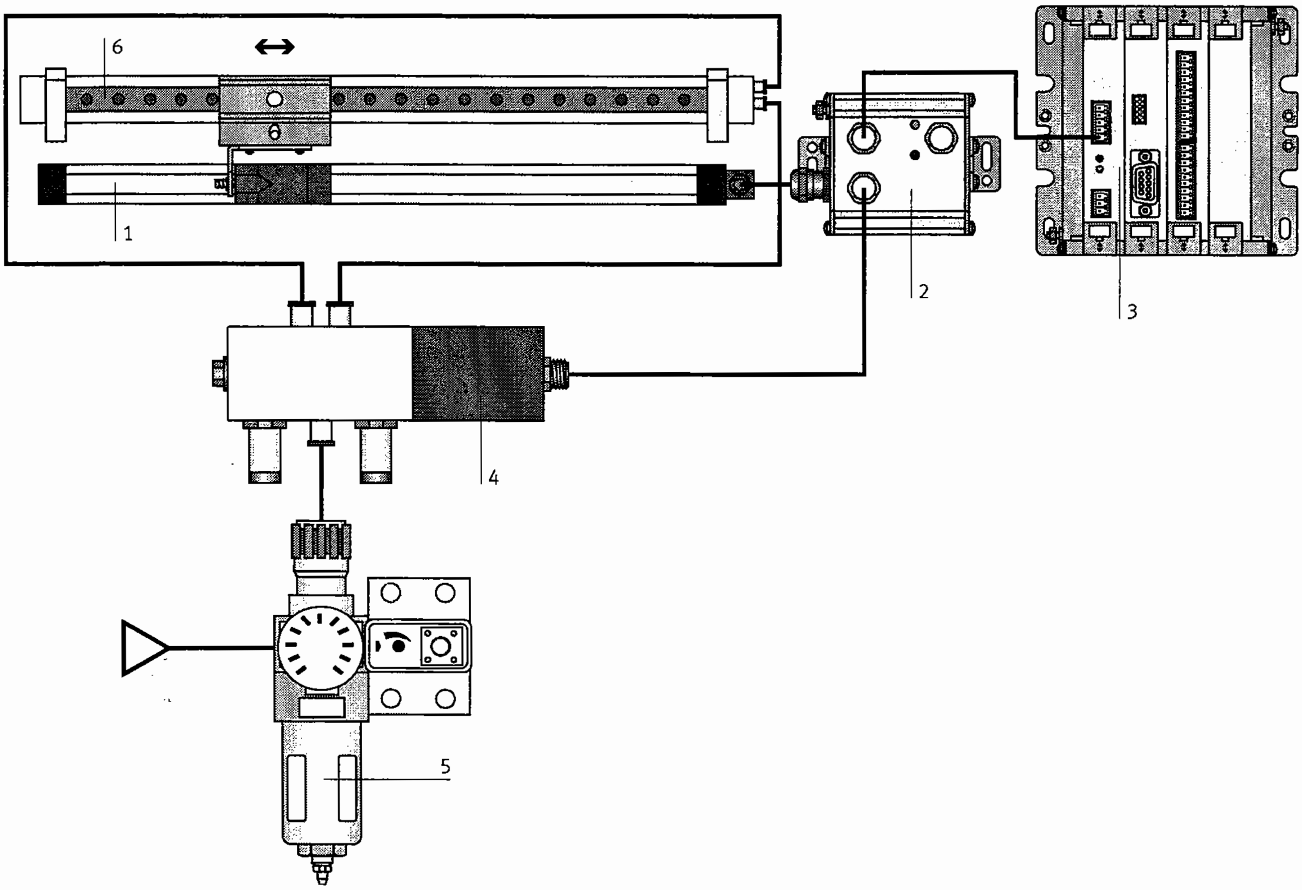
Modules of a servo-pneumatic axis

The following components are required for setting up a servo-pneumatic axis (Figure A1.1):

- A traversing slide; a guide for the slide; a double-acting cylinder drive for driving the slide (Item 6 in Figure A1.1)
- A measuring system which detects the position of the slide (Item 1 in Figure A1.1)
- An open-loop controller which monitors the process (Items 2 and 3 in Figure A1.1)
- A proportional valve which meters the flow rate (Item 4 in Figure A1.1)
- A service unit with fine filtration for protecting the proportional valve (Item 5 in Figure A1.1)

In addition, the following components are required:

- A safety device with which the automatic sequence can be interrupted in the event of an emergency
- Accessories for the mechanical set-up, for the tubing connection and for the wiring.



1	Measuring system
2	Axis interface, Type SPC-AIF
3	Smart Positioning Controller SPC200
4	Proportional Directional Control Valve, Type MPYE
5	Service unit with 5 µm filter
6	Cylinder

Figure A1.1: Modules of a servo-pneumatic linear axis

Pneumatic and mechanical components

Linear axes may be driven electrically, pneumatically or hydraulically. We use a pneumatic axis for this exercise.

A double-acting slotted cylinder is used as the drive. Slide, cylinder and guide are combined to form a linear unit in order to make this system as compact as possible. The stroke of the cylinder is 450 mm.

A 5/3-way proportional valve is used to control the cylinder (Figure A1.2). This valve has the following features:

- Flow is blocked in the centre position so that the piston can be stopped at any position between the stops.
- The required direction of movement of the piston is preset by controlling the valve accordingly.
- The valve is constantly adjustable (= proportional valve) in order to be able to regulate the flow rate and, thus, the speed of movement of the piston.
- The valve is directly actuated and electrically controlled.

Circuit diagram, pneumatic

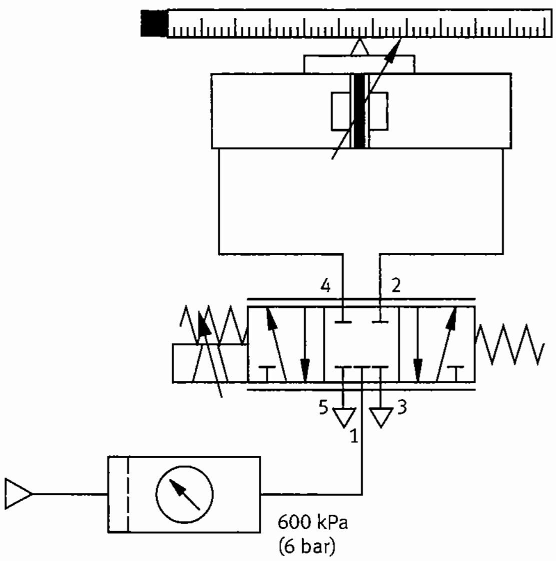


Figure A1.2: Pneumatic circuit diagram of a servo-pneumatic linear axis

Measuring system
The measuring system is a sensor which converts the position of the slide into an electrical signal.

On the pneumatic NC axis, a linear potentiometer serves as the measuring system. It is mounted at the side on the linear unit. The potentiometer's slide is connected to the slide of the linear axis by means of a driver.

Open-loop and closed-loop control
The open-loop control presets the positions which the slide is to approach. The actual position of the slide is signalled to the open-loop controller via the measuring system. The closed-loop controller forms an appropriate positioning signal for the valve from both variables.

On the NC axis, the SPC200 controller contains the electrical open-loop control and closed-loop control (Figure A1.3). The controller is of modular design and features several devices. Various stages are required depending on application. The following components are required for open-loop and closed-loop control of a linear axis:
- SPC200 controller
- Control panel
- Axis interface

Modules of the controller

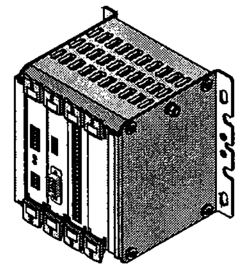
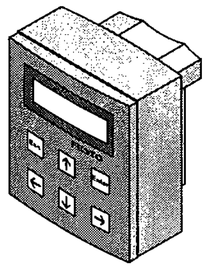
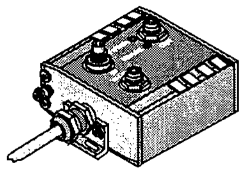
Components	Function
	SPC200, Type SPC200-...-... The SPC200 is accommodated in a rack. You may install the appropriate modules in the rack depending on the requirements of the positioning task.
	Control panel, Type SPC200-MMI-1 The control panel can be plugged on to the SPC200. It is operated via 6 keys with which all functions can be called with menu prompting.
	Axis interface, Type SPC-AIF The axis interface establishes the connection between the components on the axis and the SPC200. It receives the values supplied via the measuring system, forwards them to the SPC200 and supplies the positioning signal for the proportional directional control valve.

Figure A1.3: Modules of the controller for a linear axis

Safety devices

Shock absorbers and EMERGENCY-STOP button are required as safety devices.

- The shock absorbers absorb positioning movements which extend beyond the permitted range. They must be fitted in such a manner that they do not unnecessarily restrict the slide's range of movement.
- The EMERGENCY-STOP button serves to stop the system in the event of danger. It must be attached at an easily accessible position (electrical interconnection: see Figure A1.4).

Connection diagram, electrical

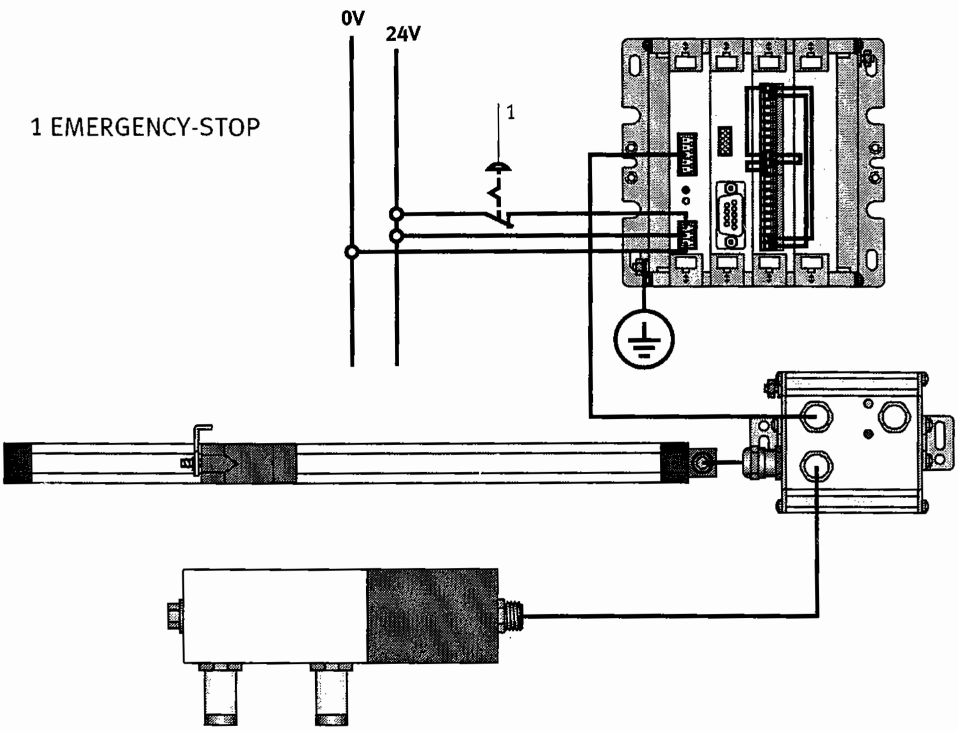


Figure A1.4: Electrical interconnection of controller, axis interface, valves and EMERGENCY-STOP

Accessories

The accessories required for setting up the system are enclosed with the equipment set. Use of the parts is either described in the assembly instructions or it can be seen from the set-up of the electrical and pneumatic circuit.

Safety measures

Keep well away from the traversing area of the slide whilst the system is operating. Risk of injury!

Problem description

A servo-pneumatic axis is to be set up. The equipment has been delivered. A location has been prepared for installation. It is now the task of the fitter to set up the system professionally at the required location.

Positional sketch

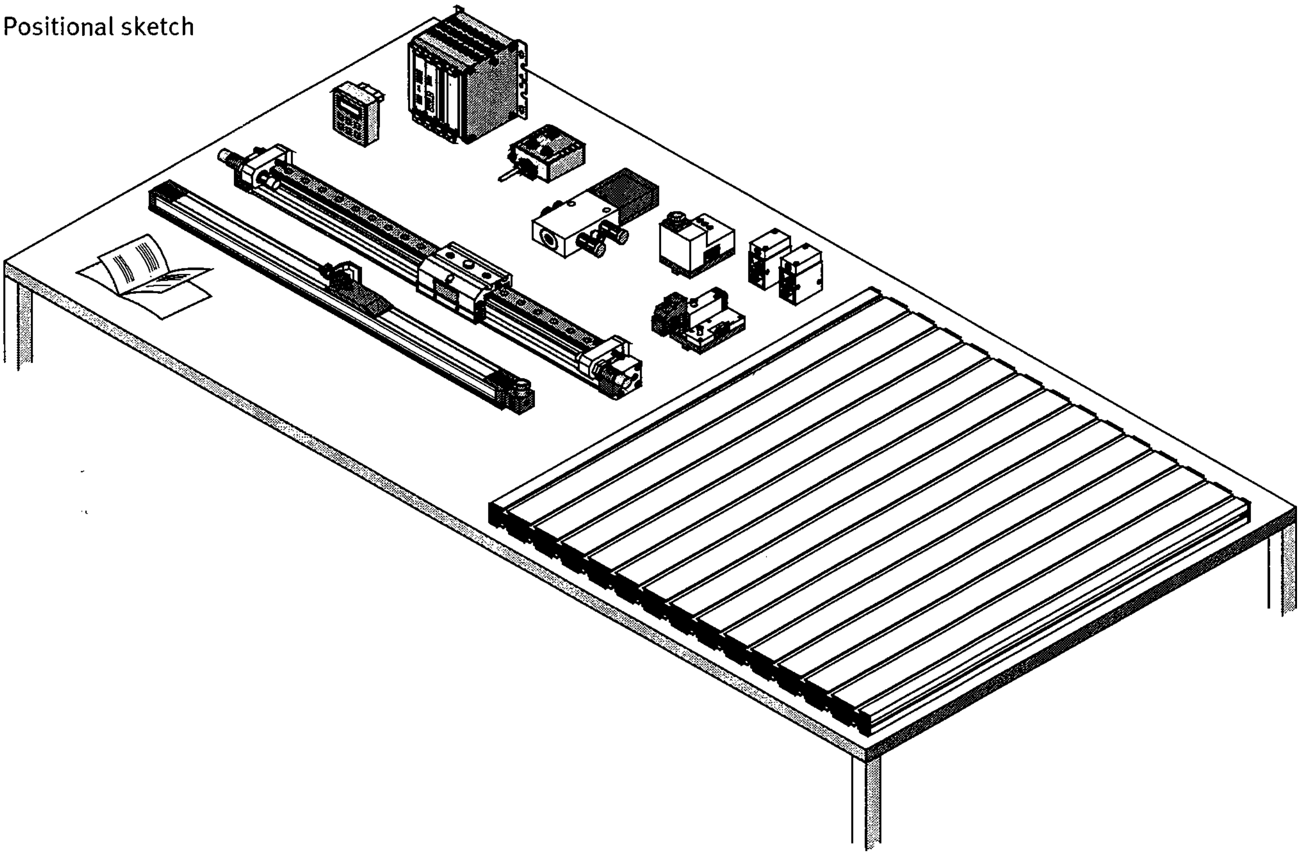


Figure A1.5: Delivered components of a servo-pneumatic axis

Problem definition

- Assembling the equipment
- Setting up the pneumatic circuit
- Setting up the electrical circuit
- Checking the overall set-up

Procedure

1. Assembling the measuring system

The measuring system must be mounted on the linear unit. Slide the slide by hand once from one end to the other in order to align the measuring system with the working stroke. If both end positions of the cylinder can be reached without the measuring system reaching its stops, the measuring system is correctly positioned and can be definitively secured.

2. Assembling the shock absorbers

Attach the shock absorbers to the linear unit. Please note the following requirements:

- The shock absorbers must be fitted as far out as possible in order not to unnecessarily restrict the range of movement of the slide.
- The shock absorbers must be attached so that they are depressed before the slide reaches the stop of the cylinder resp. of the linear guide.

3. Drawing a positional sketch

Please note the following points when drawing the positional sketch showing the arrangement of the equipment in the slotted assembly board:

- The control panel of the controller must be attached at an easily accessible point. The display must be easy to read off.
- You must be able to operate the EMERGENCY-STOP button easily.
- You must be able to observe the axis and valves.
- You must be able to easily monitor the mains voltage and supply pressure.
- Keep well away from the traversing area of the linear unit (risk of injury).

4. Mechanical construction

Set up the system mechanically in accordance with the positional sketch using the existing accessories.

5. Set-up of the pneumatic circuit

The tubing connections must be made in accordance with the pneumatic circuit diagram.

Caution

When laying the tubing, please ensure that none projects into the traversing area of the slide.

6. Set-up of the electrical circuit

The electrical interconnection is made in accordance with the block circuit diagram (Figure A1.4). Plug on the controller control panel. Use the Festo Didactic 24 V power pack as the power supply.

Caution

No cables may be routed in the traversing area of the slide!

7. Checking the set-up

- Does the layout correspond to the positional sketch?
- Are all screws firmly tightened?
- Can the slide be slid by hand between both stops preset by the shock absorbers?
- Is all tubing firmly attached?
- Are all plugs firmly attached?
- Ensure that there are no wires or tubing running crosswise over the linear unit (risk of shearing off!)
- Do the circuits correspond to the circuit diagrams?
- Is the controller with control panel easily accessible?
- Can you easily monitor supply pressure and supply voltage?

Caution

The system is not switched on until the next exercise!

Note

The slide will be traversed with high power and at high speed in the exercises which follow. Consequently, the slotted assembly board must be firmly clamped or bolted to a sturdy base!

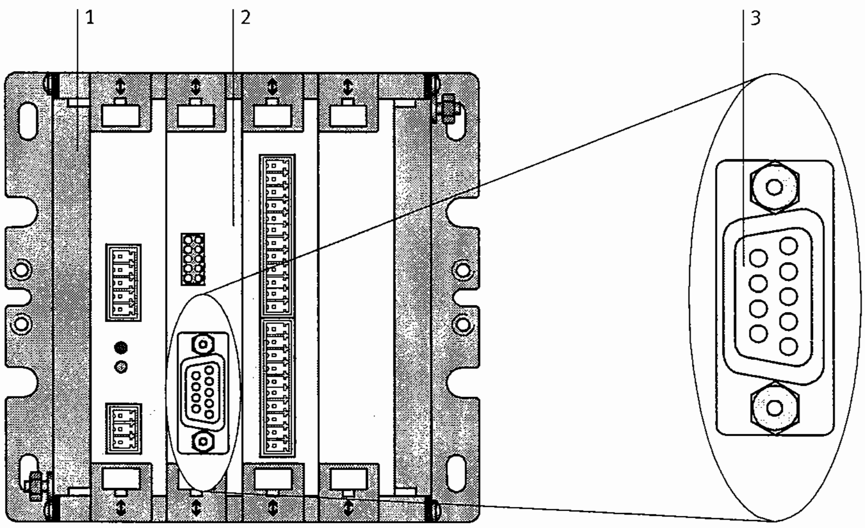
Installing the WinPISA program package
The program package is supplied on data media (diskettes) together with the Manual. Please follow the individual installation steps as specified in the WinPISA Manual (Chapters 1.1 to 1.2.2) in order to install the program package on a personal computer.

Making the connection between personal computer and controller
During commissioning, the servo-pneumatic linear axis is operated and programmed with a personal computer. The following measures are required to prepare for this:

- Connect the PC and controller using a serial interface cable (= diagnostic cable) (Figure A2.2).
- Launch WinPISA.
- Choose command "Data Transfer"" in the "Online" menu; set the PC port used (e.g. COM1) and the data rate (e.g. 38400 baud) (Figure A2.3).

Caution

The entries made in WinPISA via the PC port and the data rate used (Figure A2.3) must correspond precisely to the actual data of the PC port! Please use only the supplied diagnostic cable!



1 SPC200
2 Diagnostic module SPC200-MMI-DIAG
3 Diagnostic interface socket RS232 (X4), 9-pin

Figure A2.2: Controller interface for diagnostic cable

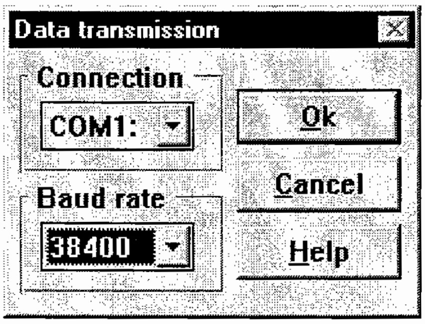


Figure A2.3: Configuring data transmission

Operating the axis via WinPISA
The connection between WinPISA and the controller must be activated. The following procedure is required:

- Switch on the electrical power supply to the controller
- Click on the "Online" menu and click on command "Online Mode" or click on the "Online Mode On" icon in the toolbar

The fact that online mode is activated can be seen from:

- the tick in the "Online" menu next to the "Online Mode" command
- the joined connectors in the toolbar

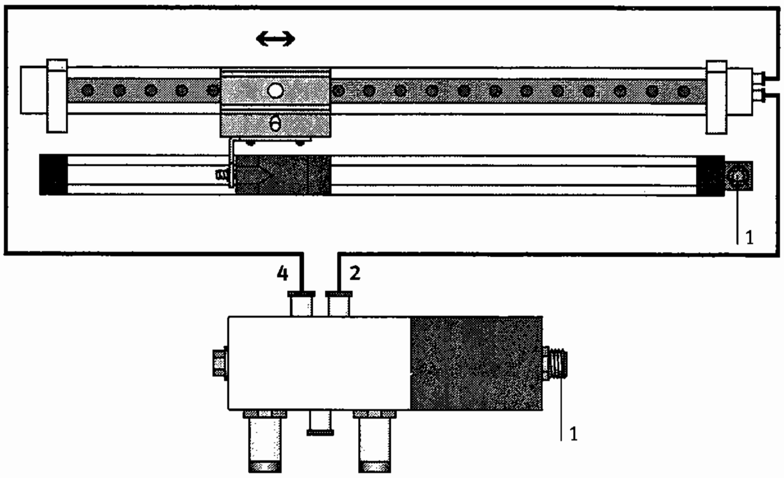
If online mode cannot be activated even after checking the cabling and electrical power supply, please refer to the WinPISA Manual, Chapter 1.6.

Control direction
The linear axis operates in a control loop, i.e.

- The desired position and actual position are compared by the controller.
- The controller computes a manipulated variable which acts on the valve.
- If there is a deviation between desired position and actual position, the valve is opened in such a manner that the slide moves to the desired position.

With the components used here, the valve port 2 must be connected to the cylinder chamber positioned on the side of the displacement measuring system plug (Figure A2.4). Only then does the slide move towards the desired position in the case of a system deviation until this desired position is reached (correct control direction).

If the ports on the cylinder are reversed, the slide moves away from the desired position under the influence of the controller. It travels at maximum force and maximum speed against the stop (wrong control direction).



1 Electrical connection

Figure A2.4: Control direction: Required tubing connection of the valve

Checking the control direction via WinPISA

Since the system may be damaged if the control direction is wrong, the control direction must be checked during commissioning via WinPISA. Perform the following steps:

- Activate Online mode (see above)
- Choose command "Motion Test" in menu "Online", "Diagnosis" (Figure A2.5)
- Confirm the warning with "Continue"

You can vary the valve's manipulated variable by clicking on the corresponding icons (Figure A2.6).

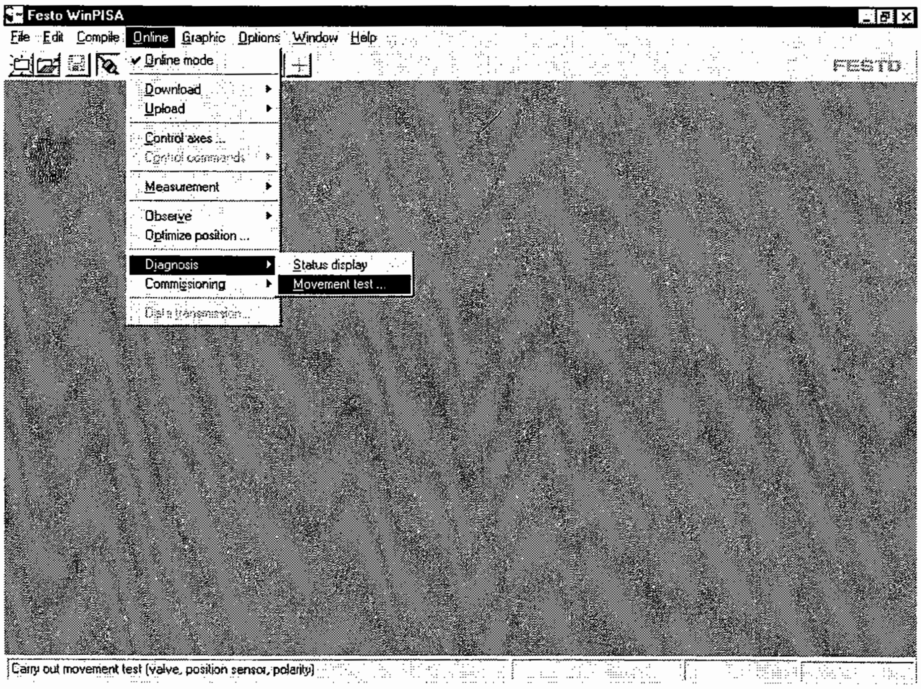


Figure A2.5: Control direction: Selecting the motion test

Exercise 2
Equipping PC boards via "pick and place"

Training aim

- To be able to install the WinPISA software
- To be able to commission a servo-pneumatic linear axis
- To be able to check the control direction of a servo-pneumatic linear axis

Technical knowledge

Programming and commissioning a servo-pneumatic axis

The servo-pneumatic axis can be programmed and put into operation in two ways:

- with the controller control panel (entry on the controller keypad, display on the controller display)
- with the WinPISA program system (entry on the keyboard of the personal computer and display on the computer monitor)

Working with WinPISA is more convenient, easier and clearer than working directly on the controller. Consequently, you are advised to perform programming and commissioning with WinPISA.

Procedure for commissioning

Commissioning a servo-pneumatic linear axis requires a step-by-step procedure (Figure A2.1).

1. Setting up the system
   The modules must be assembled and adjusted. You must also make the pneumatic and electrical interconnection (see Exercise 1).
2. Setting up the test environment
   The WinPISA software package must be installed on a personal computer. The personal computer and the SPC200 controller must be interconnected via an interface cable.
3. Switch on the electrical power supply
   Switch on the mains voltage for the control.
4. Connect the working energy and conduct a function test
   Connect the compressed air for the operating cylinder. Conduct a function test via WinPISA.
5. Program a motion sequence
   Enter the data of the pneumatic axis using the WinPISA program system on the personal computer.
   Write the program required for controlling the movement via WinPISA, check it and load it into the controller.
6. Trial run
   Test, correct and re-save the programmed motion sequence.

7. Test in continuous operation
   Call and start the motion program.
   Special safety precautions must be taken for continuous operation (e.g. screening of the moving parts).
8. Dismantle the test environment
   In continuous operation, the axis is controlled only by the controller and operated via the controller. The personal computer is no longer required. It must be disconnected from the controller

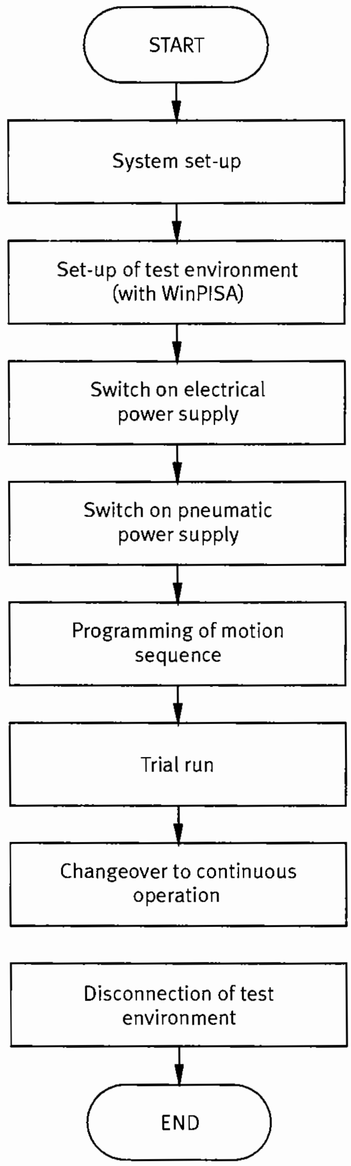


Figure A2.1: Commissioning a servo-pneumatic axis via WinPISA

Behaviour if the control direction is correct

The linear axis shows the following behaviour if the control direction is correct:

- Manipulated variable approx. 5 V:
  Slide stops.
- Manipulated variable far higher than 5 V:
  Slide moves to the right on screen.
- Manipulated variable far less than 5 V:
  Slide moves to the left on screen.

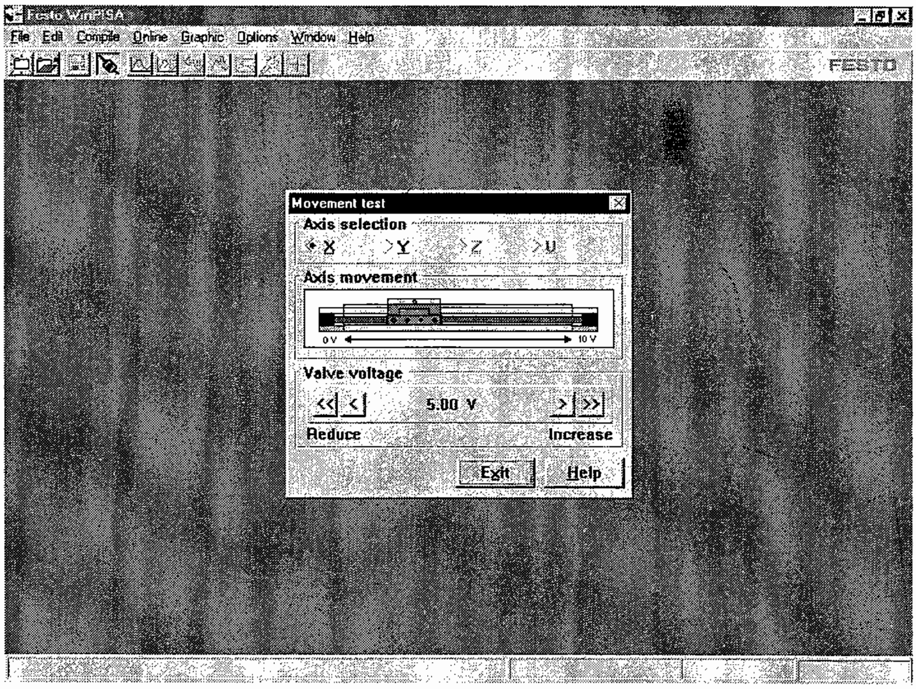


Figure A2.6: Control direction: Adjusting the manipulated variable for the proportional valve

Behaviour if the control direction is wrong

- The linear axis shows the following behaviour if the control direction is wrong:
- Manipulated variable approx. 5 V: The slide stops.
- Manipulated variable greatly differing from 5 V : The slide starts to move in the wrong direction. You will see a prompt to reverse the tubing connection on screen.

In this case, you must connect the load ports 2 and 4 of the valve to the other cylinder port in each case.

Caution

The compressed air supply must be switched off before reversing the connection of the tubing to the cylinder ports. Ensure that pressure is no longer applied!

Problem description

PC boards are to be equipped with electronic components in an assembly area. A conveyor belt transports the components to the assembly area. A gripper grips one component in each case. The NC axis is used to move the part to the scheduled position on the PC board. The gripper is then moved back to the initial position. This process is commonly referred to as "pick and place".

Positional sketch

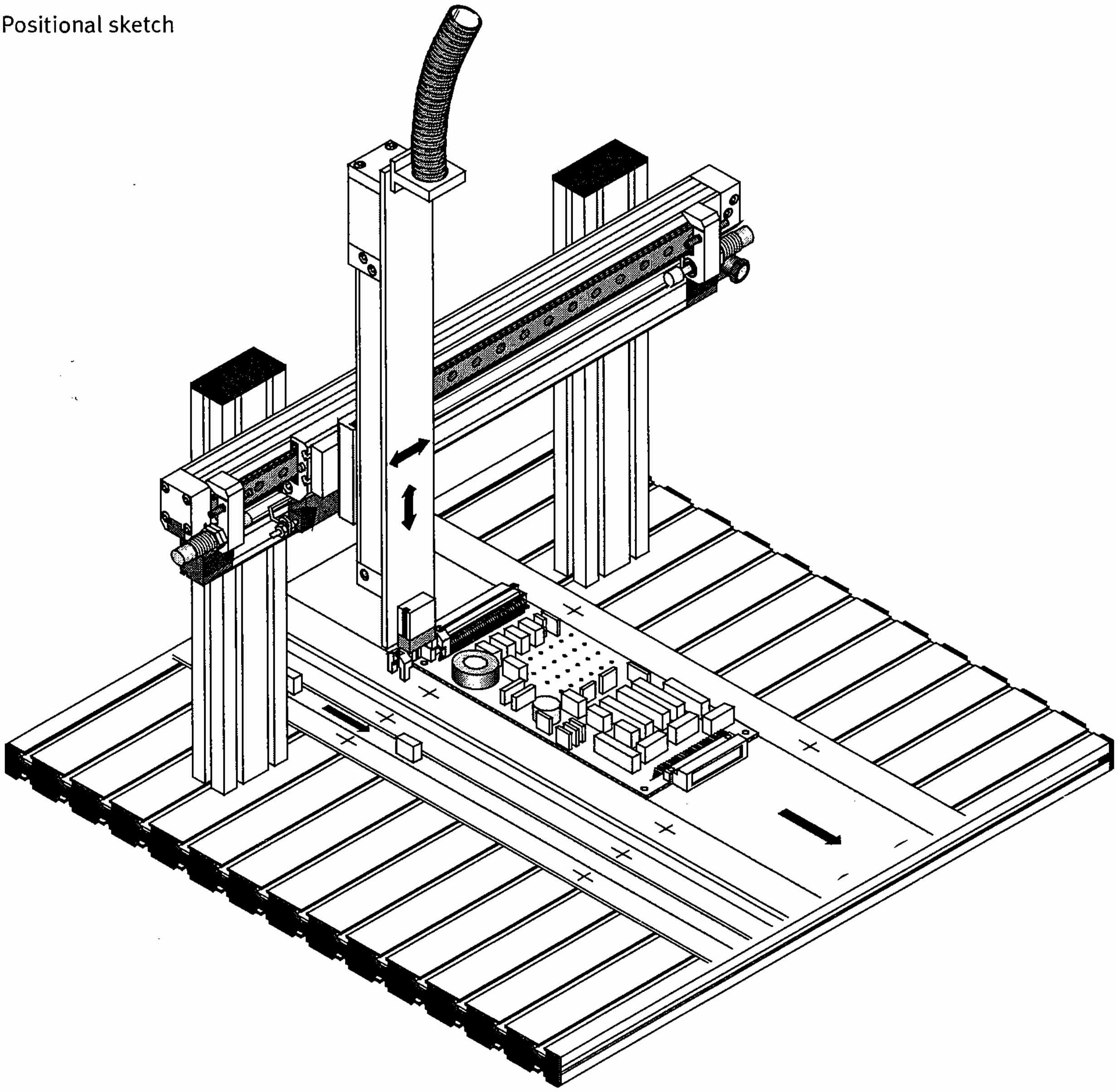


Figure A2.7: Positional sketch of the pick-and-place device

Problem definition

- Installing WinPISA
- Putting the WinPISA-controller interface into operation
- Putting the linear axis into operation electrically and pneumatically
- Remedying any faults which occur
- Checking the control direction

Procedure

The entire commissioning procedure is performed within the framework of four exercises (see Figure A2.1)

- Setting up the servo-pneumatic axis (1st commissioning step):
  Exercise 1
- Commissioning as far as the function test (steps 2 to 4):
  This exercise
- Steps 5 and 6:
  Exercise 3
- Steps 7 and 8:
  Exercise 4

1. Installing WinPISA
Check whether WinPISA is already installed on your personal computer. If it is not, please proceed as described in the section "Technical knowledge".

2. Initialising the ports between personal computer and controller
Launch WinPISA. Further procedure: See Section "Technical knowledge; making the connection between personal computer and controller".

Caution

Do not yet activate the compressed air supply or electrical power supply (24 V)!

3. Connecting the electrical power supply
Switch on the 24 V supply voltage! Check

- whether the green LED on the controller lights
- whether the control panel of the controller shows the following message:
  "SPC200 Vnnnx
  Select with ()"
  (nnn: Version number of the operating system, e.g. 224)
- whether the green LED on the axis interface lights

Should this not be the case: first switch off the supply voltage and then check the cabling.

4. Activating "Online mode"
Activate Online mode in WinPISA (see Section "Technical knowledge").
If Online mode cannot be activated, please check
- whether the supply voltage is switched on
- whether the interface cabling has been fitted correctly with the correct cable
- whether the interface configuration in WinPISA (Figure A2.4) corresponds to the port actually used on your computer

5. Connecting the compressed air
Set a supply pressure of approx. 3 bar and connect the pressure supply! The slide may not move even with the compressed air connected.

Caution

Danger: Please keep well away from the traversing area of the slide!
Do not set a supply pressure exceeding 3 bar so as to avoid damage to the axis during the test!

6. Checking the control direction
Activate the motion test in WinPISA and adjust the valve (see Technical knowledge).
Does the slide move on the screen as described in Section "Technical knowledge"?
If the slide does not move, please check the following:
- Electrical supply and compressed air supply
- EMERGENCY-STOP button (if necessary: Release the actuator; confirm the error message the next time the motion test is called).

If the slide moves but the control direction is incorrect:
- Switch off the compressed air
- Modify the tubing connection (see Figure A2.4 and Section "Technical knowledge, control direction")
- Connect the compressed air
- Recheck the control direction

7. Testing the function of the proportional valve

- Set a supply pressure of 6 bar!
- Reactivate the motion test in WinPISA.
- By clicking on the corresponding buttons, slowly move the slide approximately to the centre of the traversing range.
- Stop the slide there by clicking on the appropriate button.
- Slowly reduce the manipulated variable. Note down the manipulated variable at which the slide starts to move.
- Increase the manipulated variable. Note down the manipulated variable at which the slide starts to move in the opposite direction.
- Perform this test 3 times consecutively and, each time, note down the values of the manipulated variable.

	Manipulated variable (Motion of the slide on the screen to the left)	**Manipulated variable (Motion of the slide on the screen to the right)**
Test 1		
Test 2		
Test 3		

Table A2.1: Function of the 5/3-way proportional valve

Exercise 3
Filling a pallet

Training aim

- To be able to set up a project via WinPISA
- To be able to program a motion sequence via WinPISA
- To be able to test a program with WinPISA

Technical knowledge

Working with the WinPISA program package

The WinPISA software package is used to program and commission servo-pneumatic NC axes. It is suitable for various applications, e.g.

- for applications with one NC axis
- for applications with two NC axes
- for applications with one or two NC axes and additional functions (gripper, vacuum generator or clamping cylinder etc.)

The flow chart (Figure A3.1) shows the procedure for programming and commissioning via WinPISA. The individual steps are explained in greater detail below.

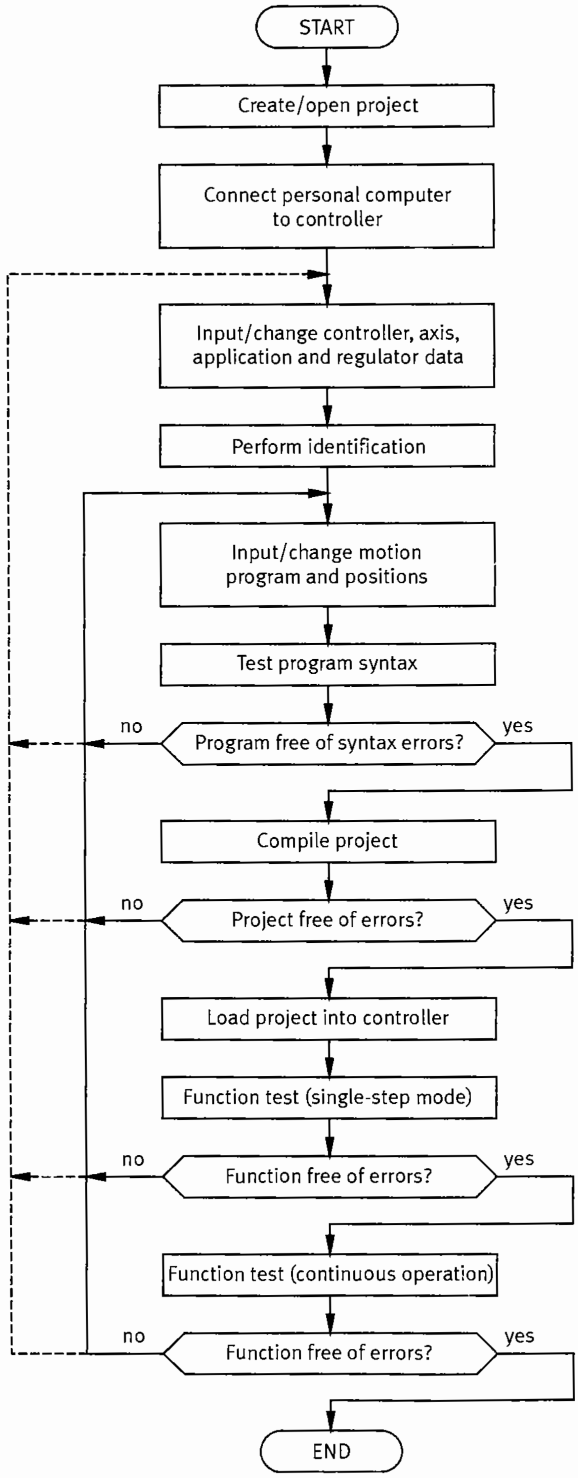


Figure A3.1: Programming and commissioning via WinPISA

Project

A project will be set up in WinPISA for each application. A project includes:

- precise information on the hardware used (controller and linear axes)
- the entire required software (program or programs for defining the movement pattern)

Creating a new project

Proceed as follows in order to create a new project:

- Choose command "Create Project" in the "File menu (or click on the "Create New Project" icon)
- Enter the name of the project
- Confirm with "Ok" (Figure A 3.2)

The new project is then shown on the screen (Figure A3.3).

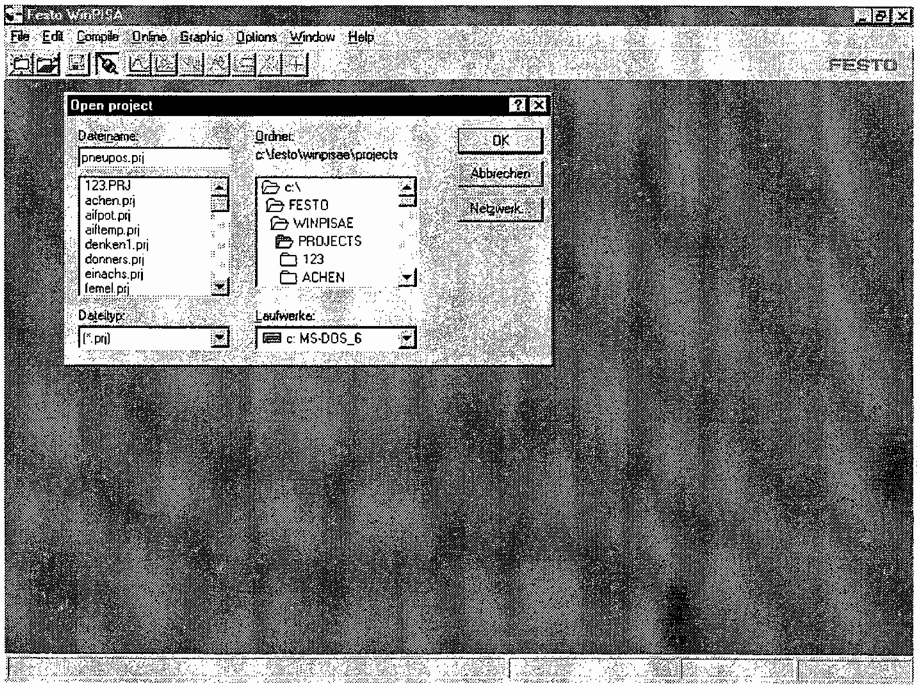


Figure A3.2: Setting up a new project via WinPISA

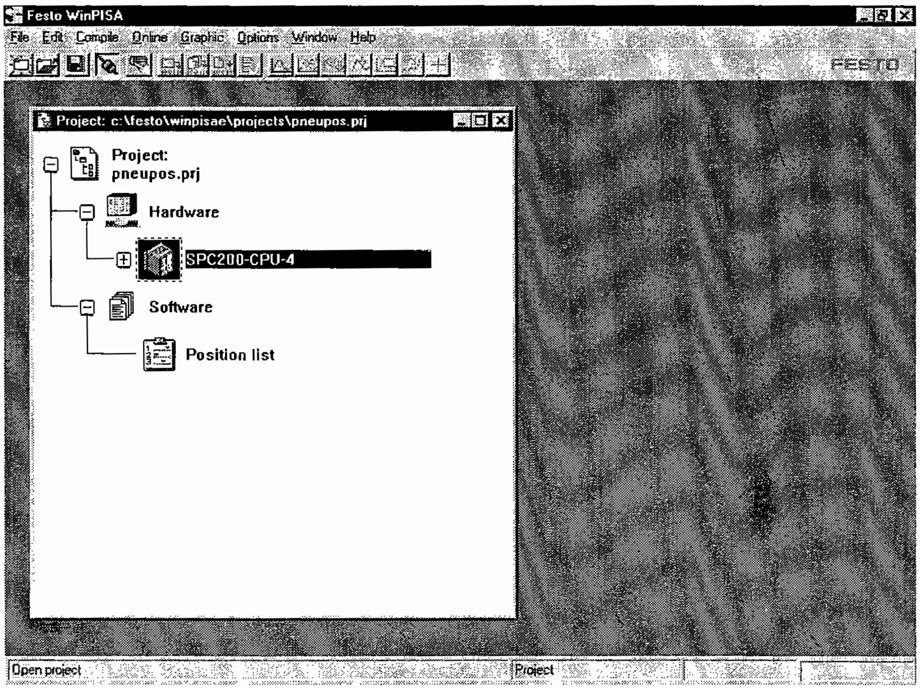


Figure A3.3: Setting up a project

Opening an existing project

You can edit an existing project stored on the computer only if it is open. You must make the following entries in order to open the project:

- Choose command "Open Project" in the "File" menu (or click on the "Open Project" icon)
- Choose the required project by clicking on it
- Confirm with "Ok"

Configuring the controller hardware

Various controller variants (controller configurations) are required, depending on the application (one axis, two axes or additional functions). The program written via WinPISA must fit the controller configuration used. The simplest and safest way of doing this to load the controller configuration directly from the controller in WinPISA.

The following entries are required:

- Activate Online mode (see Exercise 2)
- Click on the Hardware icon with the right mouse button and then on "Insert Object", "Controller SPC 200"
- Click on "Upload" (Figure A3.4)
- Confirm with "Ok"

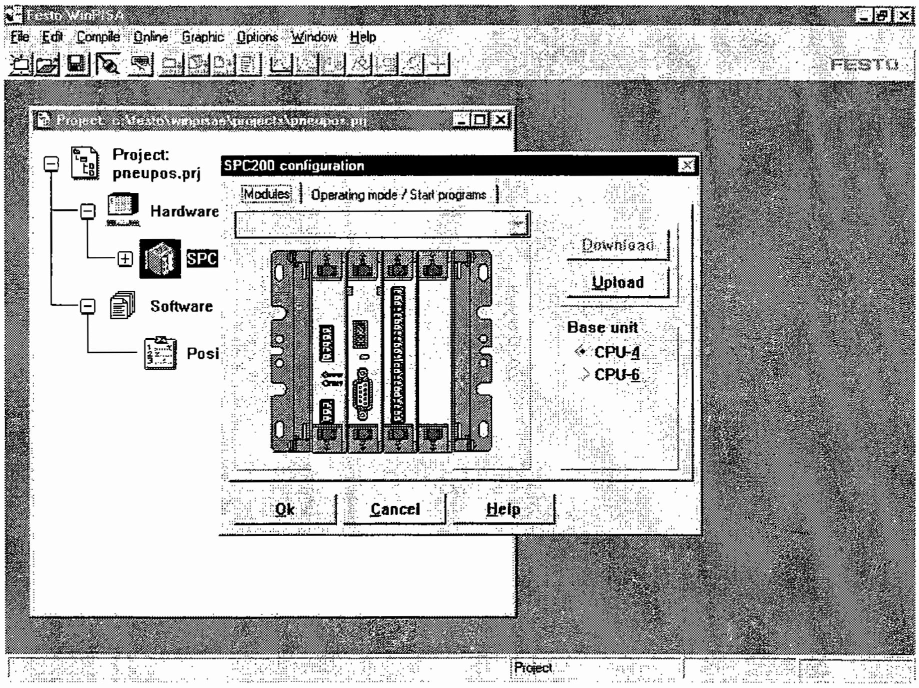


Figure A3.4: Configuring the controller

Configuring the linear axis

The linear axis used here has the following components:

- A rodless cylinder with 25 mm diameter and 450 mm stroke
- A potentiometric displacement measuring system with a measuring length of 450 mm
- A proportional valve of nominal diameter 1/8 inch with flow factor 1

The following entries are required in order to configure the linear axis:

- Click on "SPC200" with the right mouse button and then on "Insert Object" and "Positioning Axis"
- Select the appropriate cylinder type (Figure A3.5)
- Confirm your selection with "Ok"

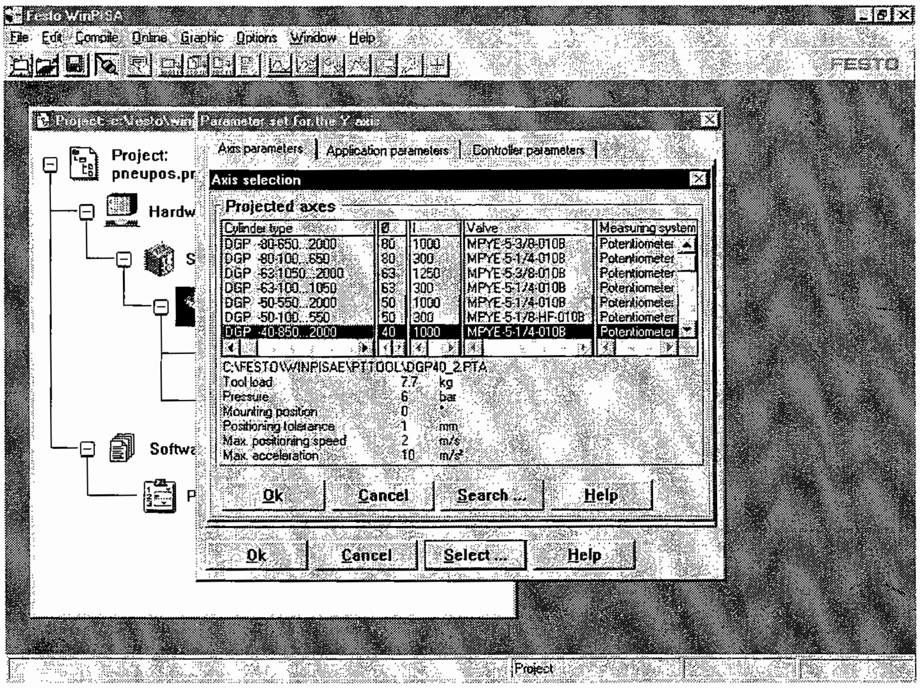


Figure A3.5: Configuring the linear axis (positioning axis)

Entering and changing the axis data

Axis data, application data and controller data can be entered and changed only if you have configured the linear axis beforehand.

The following steps are required in order to enter or change the axis data:

- Choose "Positioning Axis" in the Project window with the right mouse button
- Click on the "Axis Data" field
- Enter the cylinder length, potentiometer length and flow factor of the valve (Figure A3.5)
- Confirm your entry with "Ok"

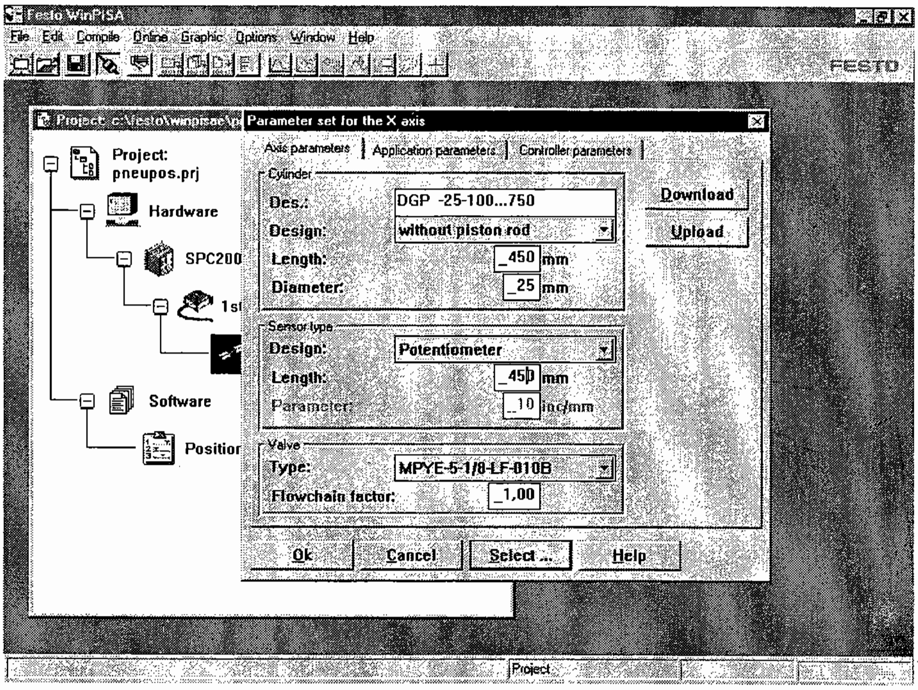


Figure A3.6: Entering the axis data

Entering and changing the application data
You must click on the Application Data button in the "Positioning Axis" Project window in order to be able to display or change the application data.

Correct functioning of the servo-pneumatic NC axis is achieved with the application data specified in Figure A3.7. The significance of the data is explained in the WinPISA Manual, Chapter 4.4.2.

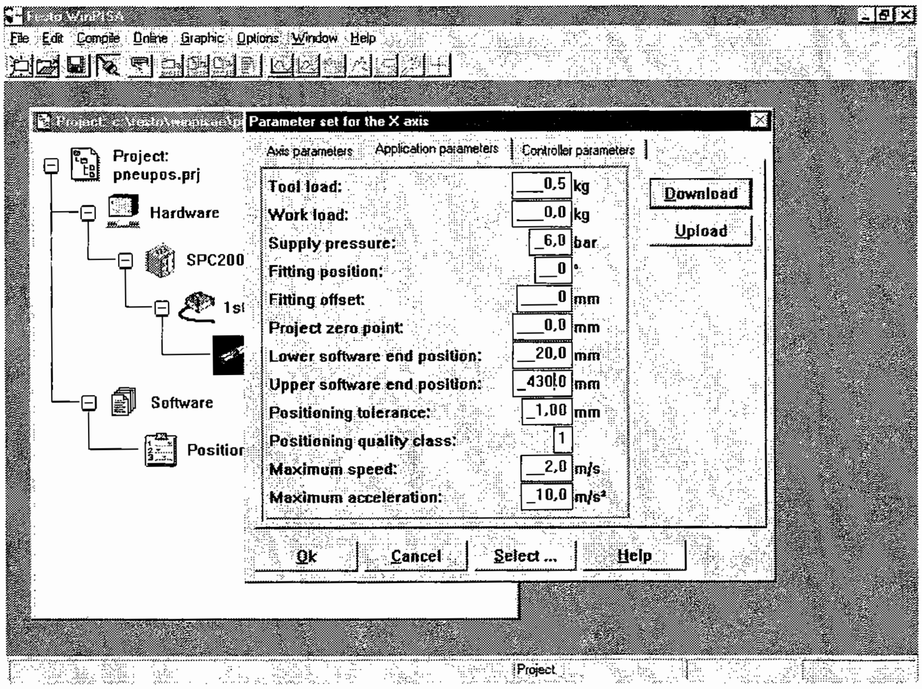


Figure A3.7: Entering the application data

Defining the controller data

The controller data is displayed if you click on the "Controller Data" button in the "Positioning Axis" Project window. You will see the data shown in Figure A3.8. This data should not be changed!

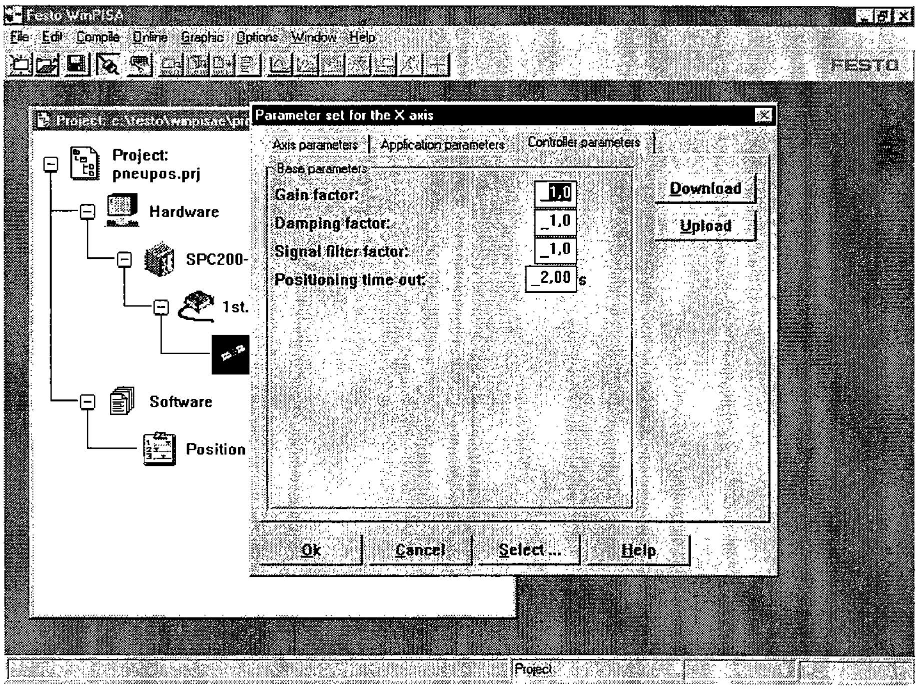


Figure A3.8: Controller data

Identification

The motion behaviour of a servo-pneumatic linear axis is influenced by numerous characteristics. Certain characteristics are subject to variation within series or are greatly dependent on the application. Examples are as follows:

- The manipulated variable at which the valve is closed
- The frictional force of piston seal and linear guide

These characteristics are not known to the user and can thus not be entered as axis or application data. They are determined by an identification which covers the following functions:

- The manipulated variable for the valve is varied on the basis of a stipulated procedure
- The motion behaviour of the slide is measured.
- The characteristics influencing the controller setting are computed from the measured results.

Static identification suffices for the problem definition in question. If the movement speed of the axis is to be further-optimised, a dynamic identification will also be required.

The static identification is started as follows:

- Ensure that Online mode is active
- Choose command "Identification" in menu "Online", "Commissioning"
- Confirm the message with "Continue"
- Choose "Axis X" and "Static Identification" (Figure A3.9)
- Click on "Start"

Caution

- The supply pressure during the identification must correspond to the supply pressure during the subsequent application (generally 6 bar)!
- Risk of injury: During identification, the slide is traversed at high force and at high speed!
- Identification takes quite a while because the NC axis performs numerous movements which must also be evaluated.

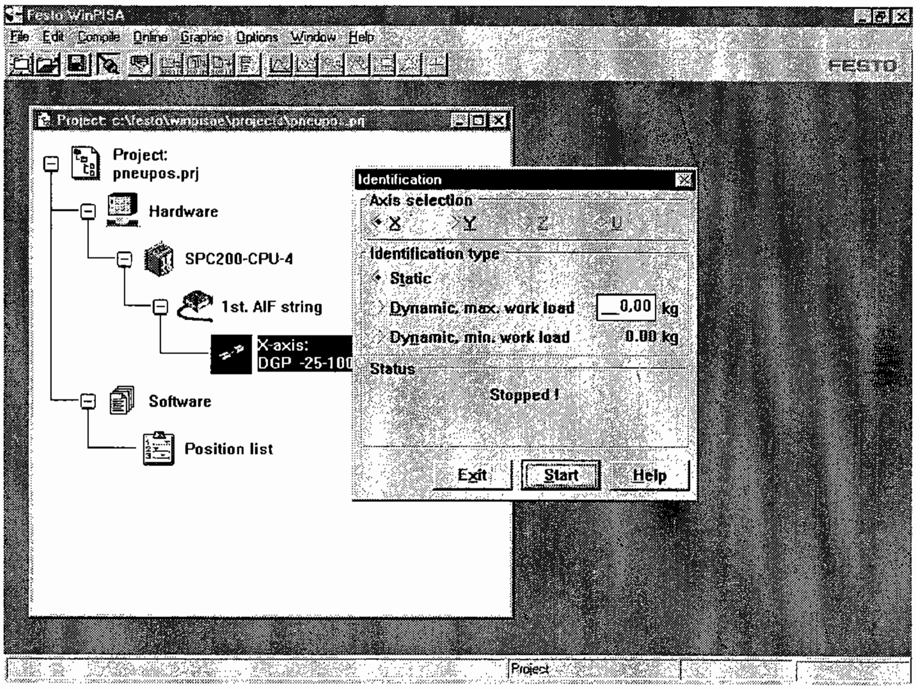


Figure A3.9 Static identification

Structure of an NC program

The servo-pneumatic linear axes are programmed by analogy with DIN 66025.

NC words form the basis of this programming language. NC words frequently used and their significance are summarised in Figure A3.10.

Each NC block consists of NC words (Figure A3.11). It is written into a program line and contains block number (e.g. N00), command (e.g. G01) and related parameters (e.g. X100 FX50).

All NC blocks taken together form the NC program

Function	**NC word**	**Significance**
Block number	N10	Number of the NC block
Preparatory condition	G00 G01 G04	Approach to a position in the quickest way Travel at reduced speed Dwell time of x • 0.01sec
Coordinates	X100 Y300	Positioning the X axis to within 100 mm Positioning the Y axis to within 300 mm
Feed	FX00 FX01 FX99	Maximum speed v_{max} 1 % of v_{max} 99 % of v_{max}
Additional function	M02 M30	End of subroutine End of program with program retry

Figure A3.10: Significance of NC words frequently used

NC block	**Description**
N000 G01 X100 FX50	Move at 50 % of the defined maximum speed to position X = 100 mm
N001 G04 100	Dwell time of 1 sec
N002 G01 400 FX50	Move at 50 % of the defined maximum speed to position X = 400 mm
N003 G04 100	Dwell time of 1 sec
N004 M30	End of program and retry

Figure A3.11: NC program with description of the NC blocks

Creating a new program

You must first create the program when creating a new project. This will require the following steps:

- Click on the Software icon in the Project window
- Enter the program title, program description and program number (Figure A3.12)
- Confirm the entries with "OK"

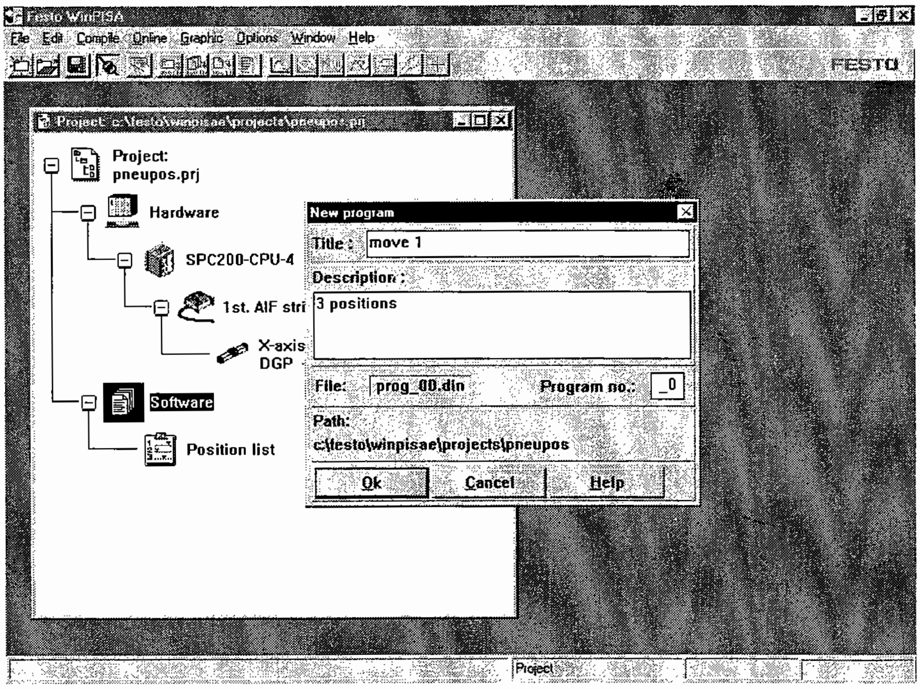


Figure A3.12: Creating a new program (example)

Creating a new program

You must first create the program when creating a new project. This will require the following steps:

- Click on the Software icon in the Project window
- Enter the program title, program description and program number (Figure A3.12)
- Confirm the entries with "OK"

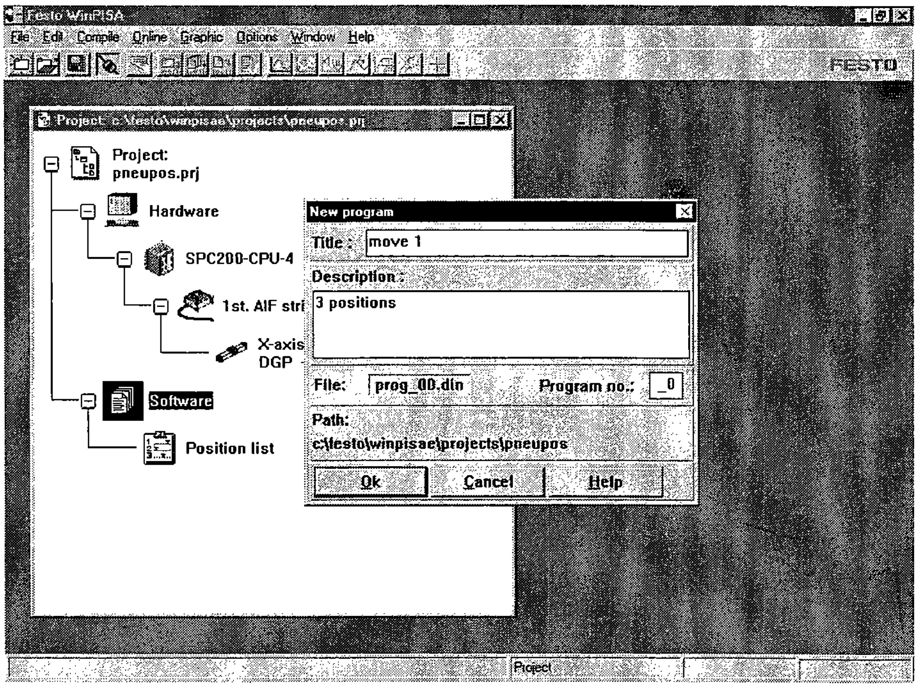


Figure A3.12: Creating a new program (example)

Entering or changing an NC program

Proceed in the following order to enter a new NC program or change an existing NC program:

- Choose the Program icon in the Project window
- Press the Return key (= Open the program)
- Enter the program text (Figure A3.13)

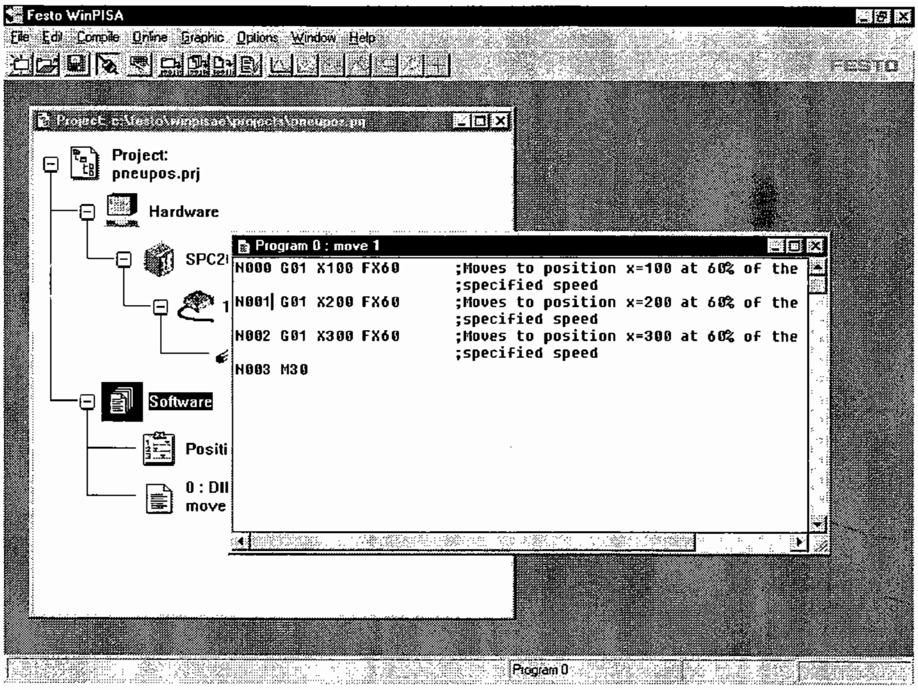


Figure A3.13: NC program (Program window of WinPISA)

Checking the program syntax

You can check the following via WinPISA

- Whether individual NC words have been written correctly
- Whether the NC words have been combined admissibly to form NC blocks
- Whether all NC blocks together form a program

The check is started in the "Compile" menu with the "Syntax Check" command (resp. by clicking on the "Syntax Check" icon). Progress of the check is displayed in a window. Confirm completion of the check with "Ok".

Correct the specified blocks if you receive error messages. You will then need to conduct a syntax check again.

The program must be saved to hard disk in order to save the changes made (click on "File", "Save" or click on the "Save Active Window" icon).

Compiling the project

Choose the "Project" command in the "Compile" menu. When compilation is complete, check the message window. Any errors displayed must be corrected. You must then compile again.

Loading the project to the controller

The compiled project must be loaded from the personal computer into the controller. Do this in the following order:

- Switch on the controller's electrical power supply
- Activate Online mode
- Choose command "Project" "in menu" Online", "Download"
- Click on "Continue" after the warning message
- Wait until the project has been loaded (this will be displayed on the screen)
- Confirm successful loading with "Ok"

Testing the program in single-step mode
An NC program can be tested block-by-block or step-by-step via WinPISA. The following preconditions must be met:

- The controller's supply voltage must have been switched on.
- Online mode must have been activated.
- The project with the program to be tested must have been loaded into the controller beforehand.
- The compressed air supply must have been switched on.

The test is conducted as follows:

- Choose command "Control Axes" in the "Online" menu.
- Choose the program to be tested in the Program window and confirm with "Ok"
- Confirm the warning message with "Continue"
- Choose the required NC block with the arrow keys (Figure A3.14)
- Activate the NC block with the right mouse button and click on "Execute Step"

The NC axis executes the selected program step. The step pointer then moves automatically to the next NC block. The entire program can be executed by repeatedly clicking on "Execute Step".

Caution

The axis performs movements with high force and at high speed during the test!

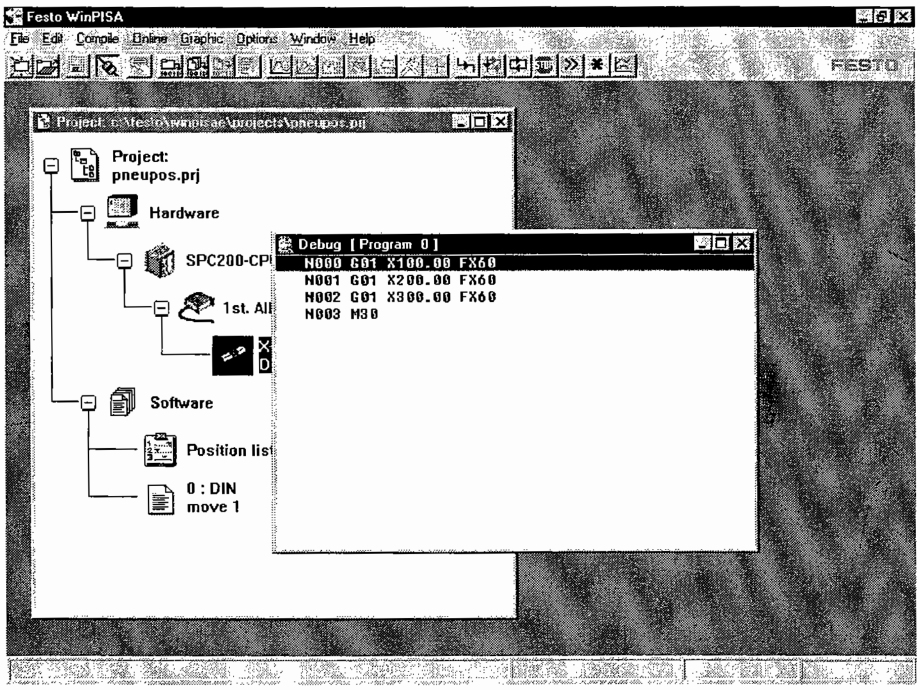


Figure A3.14: Testing the motion program

Clearing faults

If the slide of the axis does not move as required, perform the following work steps (Figure A3.1):

- Localise the fault (determine the incorrect NC blocks)
- Modify the program
- Recheck the syntax
- Recompile the project
- Reload the project
- Test again in single-step mode

Testing the program in continuous operation

Continuous operation is activated in the "Online" menu by clicking on the "Control Commands" and "Start Continuous Operation" buttons.

You can abort continuous operation by clicking on "Stop".

Problem description

Jars are to be supplied individually on a conveyor belt on a packaging system. A handling device with servo-pneumatic NC axis has the task of transferring these jars to a pallet. The NC axis must position the gripper so that the pallet is filled systematically.

Positional sketch

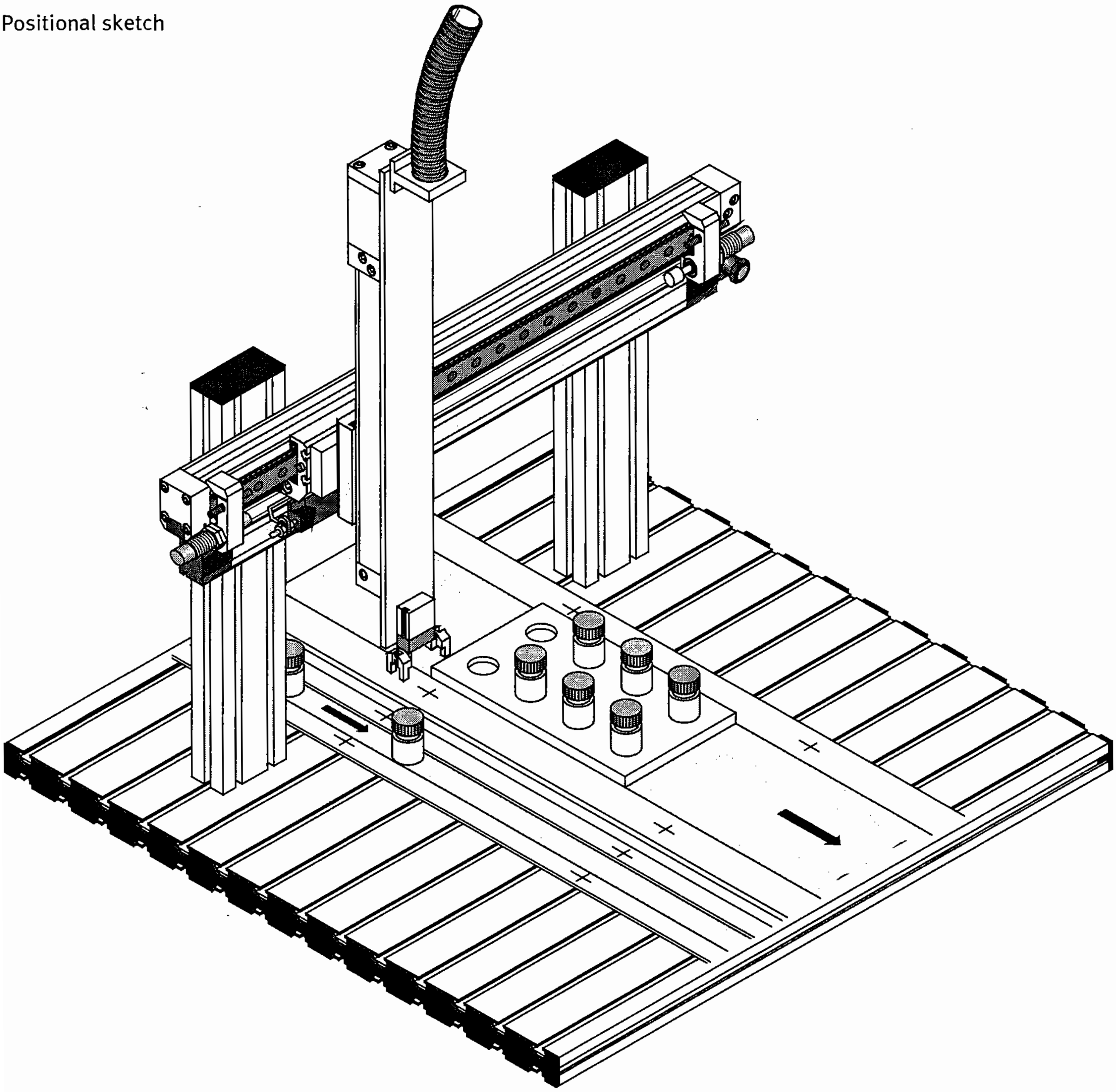


Figure A3.15: Positional sketch of the packaging system

Problem definition

- Creating the project
- Configuring the project
- Writing the motion program
- Testing the motion program

Procedure

1. Creating the project
Create a project named "Package"!

2. Configuring the hardware
Configure the following for this project
- Controller
- Axis data
- Application data

The power supply to the controller must be switched on for this operation. For the time being, the compressed air supply remains disconnected.

3. Program design
Write the NC program for the packaging device (Figure A3.15). The program must meet the following requirements:
- The jars arrive at position x = 100 mm and are picked-up from there.
- The jars are deposited alternately at position x = 300 mm and x = 400 mm.
- The system must wait two seconds at each position in order to ensure pick-up or deposit of the jar.
- As soon as two jars have been deposited, the motion cycle starts again from the start.

All movements must be performed at 60 % of the maximum speed.

4. Entering and compiling the program
- Enter the NC program you have designed and conduct a syntax check.
- If syntax errors are displayed, you must remedy these and recheck the syntax.
- Compile the entire project.
- Should errors have occurred during compilation, you must remedy the errors and recompile the project.

5. Loading the project
Load the project into the controller.

6. Program test in single-step mode
Test your program in single-step mode.
If the slide of the positioning axis does not move as required, please proceed as described in Section "Technical knowledge" under "Fault-clearance".

7. Program test in continuous operation
Start continuous operation and observe the movement of the slide.

8. Slow movement speed
- Modify your program so that the axes traverse at 10 % of the maximum speed.
- Save the modified project under name "PackageS".
- Test the program and observe the movement of the slide.

9. Fast movement speed
- Modify your program so that the axes traverse at maximum speed .
- Save the modified project under the name "PackageF".
- Test the program and observe the movement of the slide.

Exercise 4
Sorting gear wheels

Training aim

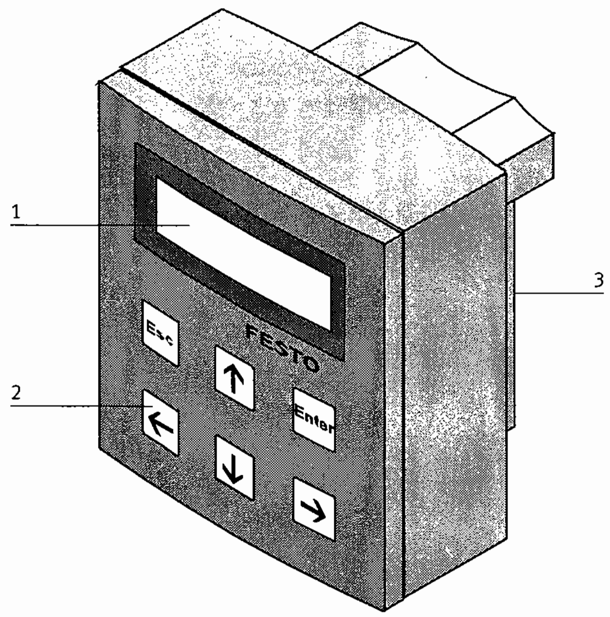
- Familiarising yourself with the function of the controller control panel
- Controlling simple functions with the controller control panel
- Being able to perform recommissioning in the case of EMERGENCY-STOP

Technical knowledge

Controller control panel: Scope of functions
Exercises 2 and 3 described how a servo-pneumatic NC axis is configured, programmed and put into operation via WinPISA.

These work steps can also be performed without WinPISA. In this case, all entries are made on the keypad of the controller control panel and all acknowledgements are made on the related display (Figure A4.1).

Activating functions with the controller keypad sometimes requires numerous keystrokes, and the controller display can only display a little information at the same time. Consequently, configuring and programming are more time-consuming than with WinPISA.



1 Display (liquid-crystal display with 2 x 16 characters)
2 Touch-sensitive keypad
3 Interface to the SPC200 on the rear side

Figure A4.1: Control panel of the controller SPC 200

Procedure in practice
In practice, all work on the NC axis must be performed as quickly and as economically as possible. Consequently, this work must result in only slight effort. The following procedure has proven practical:

- Configuration, programming and commissioning are performed via WinPISA (advantages: less work required than when using the controller control panel, additional saving of the project on the personal computer's hard disk).
- After completion of commissioning, the personal computer is then disconnected (advantage: PC can be used for other tasks).
- During operation of the NC axis, the program is started and stopped with the controller control panel (operating mode: continuous operation).

Faults when operating the axis
If a fault occurs in continuous operation, please perform the following steps:

- Localise the fault and determine the cause of the fault
- Remedy the fault
- Restart the motion program (operating mode: continuous operation).

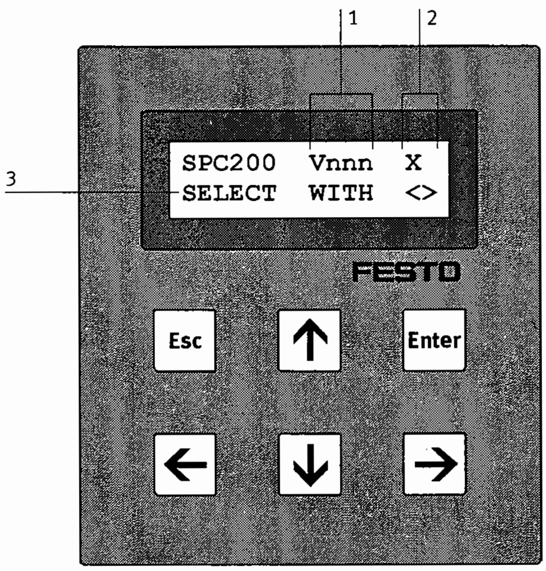
All steps can be performed with the control panel of the controller. When localising the fault, the controller's diagnostic functions will also help you. These can also be activated via the control panel.

Almost all faults that occur during operation of a servo-pneumatic NC axis can be remedied without WinPISA.

Keys and displays of the control panel

The keys and the display of the control panel are shown in Figure A4.2.

- The keys are used to select and execute the controller functions.
- The display provides information on the status of the controller and information on what function has been activated with the control panel. In normal mode, you will see the information shown in Figure A4.2 on the display.



1 Operating system version of the SPC200 (nnn = Version number: The dot after the main version code is not displayed owing to reasons of space: nnn corresponds to n.nn)

2 Currently configured axis (the X axis is preset as default)

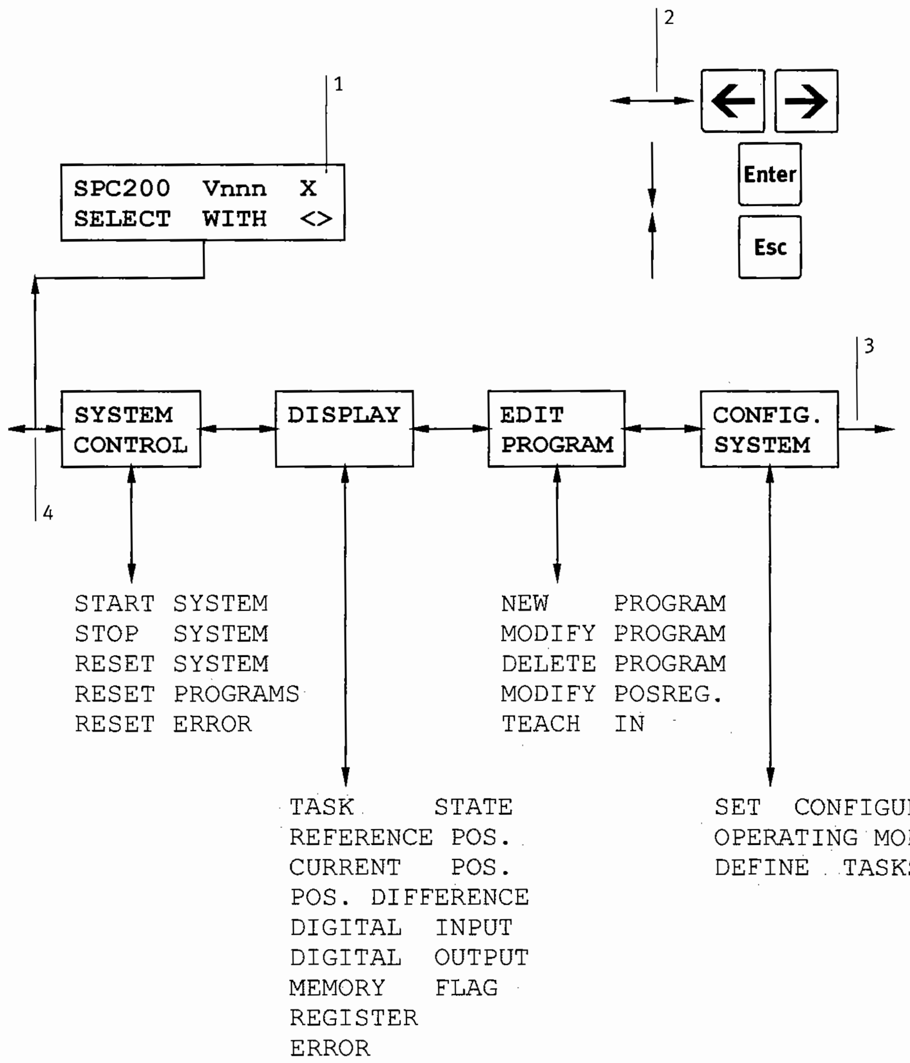
3 Information bar: You make your menu selection with ← →

Figure A4.2: Keys and displays of the controller control panel

Levels of controller operation

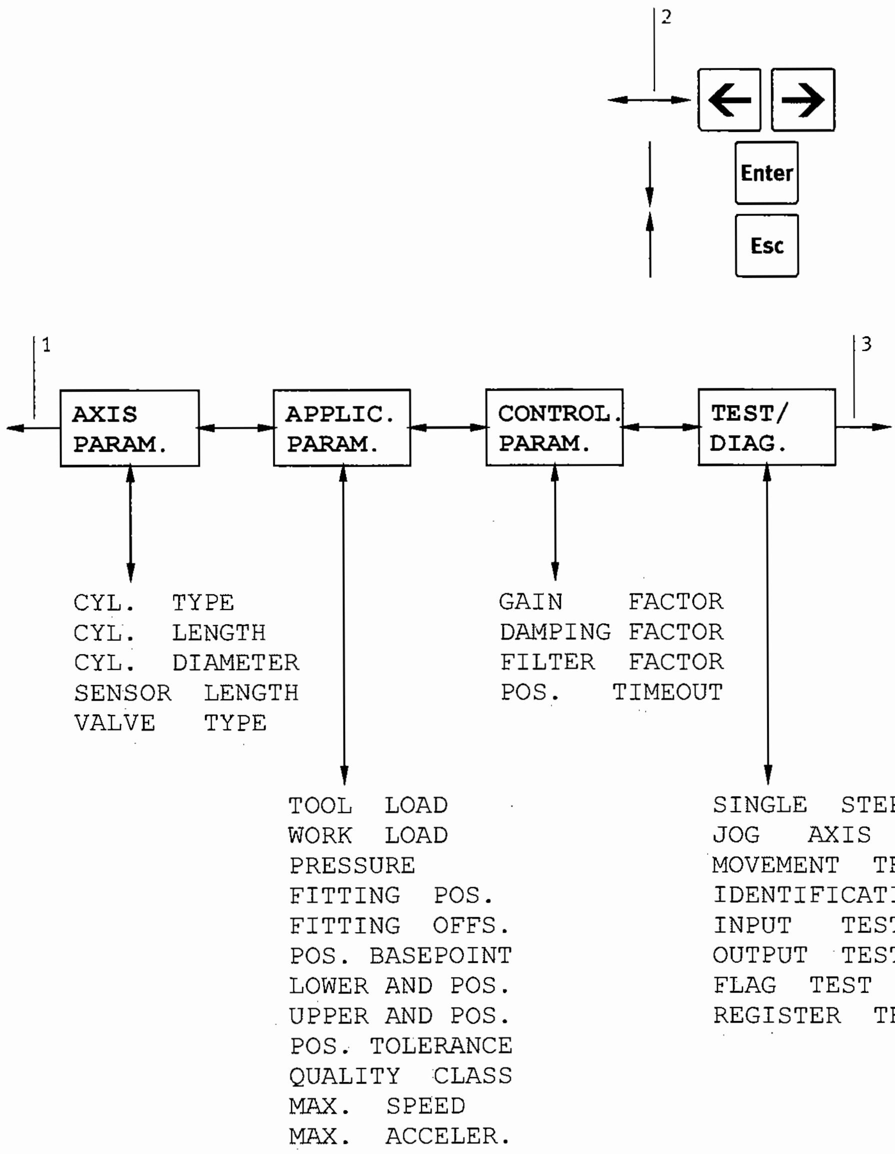
Controller operation is split into various levels owing to the numerous functions (Figures A4.3 and A4.4).

- The arrow keys are used to move within one level (in horizontal direction).
- Pressing the "Enter" key, skips to the level beneath.
- Pressing "Esc" (Escape) skips to the level above.



1 Basic setting
2 Navigating in the menu system
3 See next page AXIS PARAM
4 See next page TEST/DIAG

Figure A4.3: Figure showing levels of the controller control panel



1 Previous page CONFIG. SYSTEM
2 Navigating in the menu system
3 See previous page SYSTEM CONTROL

Figure A4.4: Levels of the controller control panel (continued)

Purpose	Press
Confirm current selection and move one level down if necessary	Enter
Make different selection in same menu level	← →
Abort selection and move one level up	Esc

Figure A4.5: Navigating in the controller's menu system

Operating the controller: Starting the NC axis

We are faced with the following initial situation: The motion program of the NC axis is not active. The slide of the NC axis has stopped.

The following procedure is required in order to start the movement operation:

- Press the "ESC" key until the display on the controller corresponds to Figure A4.2
- Press an arrow key until you see "System control"
- Press the "Enter" key
- Press an arrow key until "Start system" is shown in the display
- Press the "Enter" key

Operating the controller: Stopping the NC axis

We are faced with the following initial situation: The slide of the NC axis is moving in continuous operation.

Movement of the NC axis is stopped with the following key combination:

- Press the "ESC" key until the controller display corresponds to Figure A4.2
- Press an arrow key until you see "System control"
- Press the "Enter" key
- Repeatedly press an arrow key until "Stop system" is shown on the display
- Press the "Enter" key

Operation of the controller: Fault clearance

We are faced with the following initial situation:

- The EMERGENCY-STOP button has been pressed.
- The slide of the axis has stopped.
- The red pilot LED of the controller is flashing. The display of the control panel displays "Error".

Proceed as follows in order to clear the fault:

- Disconnect the compressed air supply
- Remedy the fault or the danger situation
- Pull the EMERGENCY-STOP button
- Press button "Esc" until the display corresponds to Figure A4.2
- Press an arrow key until you see "System control"
- Press the "Enter" key
- Press an arrow key several times until you see "Reset Error" on the display
- Press "Enter". The red pilot LED of the controller goes out

Then connect the compressed air. The procedure required for restarting is outlined under "Operation of the controller: Starting the NC axis".

Problem description

Gear wheels are ground during production of transmissions. The ready-machined gear wheels are transported on a conveyor belt to an inspection station. Since the quality inspection takes longer than the cycle time of the production plant, two automatic inspection units are used. A gripper picks-up a gear wheel from the conveyor belt and deposits it alternately into one of the two automatic inspection units.

Positional sketch

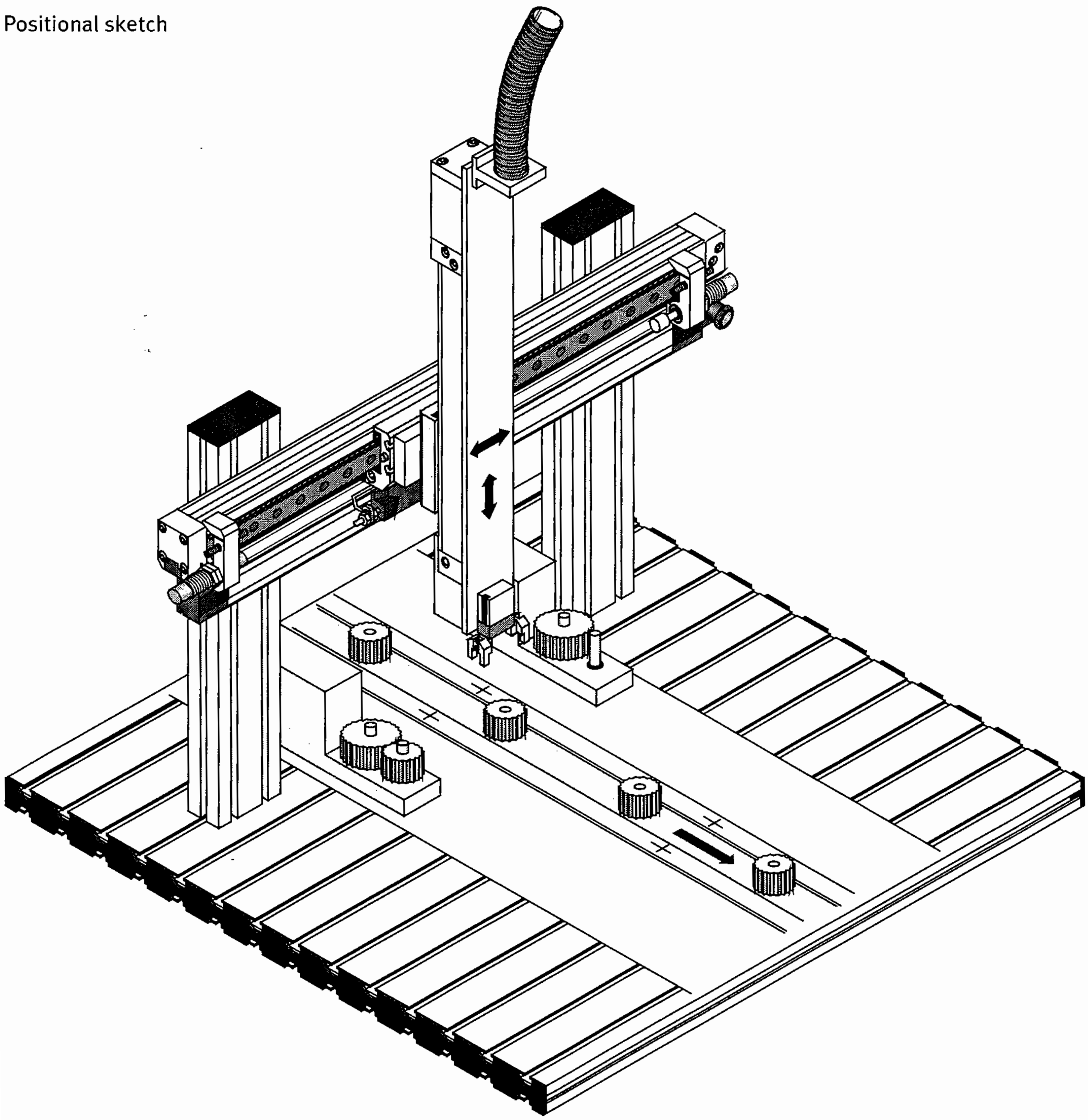


Figure A4.6: Positional sketch of the inspection device for gear wheels

Problem definition

- Writing an NC program
- Program test via WinPISA
- Remedying an EMERGENCY-STOP situation via WinPISA
- Operating an axis using the controller control panel
- Remedying an EMERGENCY-STOP situation using the controller control panel

Procedure

The NC axis is first configured, programmed and operated using WinPISA (work steps 1 to 4). The procedure for using WinPISA is explained in Section "Technical knowledge" of Exercise 3.

The procedure for performing work steps 5 and 6 is outlined in Section "Technical knowledge" of this exercise.

1. Creating a new project

- Open a new project named "Gear Wheel" in WinPISA.
- Configure the axis in accordance with Exercise 3.

2. Writing a new program

The following boundary conditions must be observed for the NC program for the inspection device:

- The pick-up position for the gear wheels is x = 200 mm.
- Inspection device 1 is located at x = 360 mm.
- Inspection device 2 is arranged at x = 40 mm.
- The slide should wait 1 second at each position.
- All movements should be performed at maximum speed.

Write the NC program! Proceed as follows:

- Design the program!
- Enter the program.
- Conduct the syntax check and compile the project.
- Remedy any faults which may have occurred!
- Load the error-free project into the controller!

3. Testing the program via WinPISA

Test the motion program with WinPISA!

- Are the correct positions approached?
- Are the waiting times correct at all positions?
- Have the right movement speeds been programmed?

Remedy any faults that may have occurred!

4. Remedying an EMERGENCY-STOP situation via WinPISA

- Operate the linear axis in continuous operation!
- Press the EMERGENCY-STOP button!
- What must you do in order to put the axis back into operation again using WinPISA? Take the required steps.
- Note down the required steps for remedying an EMERGENCY-STOP situation using WinPISA.

5. Controlling an NC axis with the controller control panel

The following steps must be performed as a preparatory measure:

- If the slide of the NC axis is still moving, stop the movement with WinPISA.
- Switch off the compressed air supply!
- Quit WinPISA.
- Switch off the computer. Switch off the controller's power supply!
- Disconnect the diagnostic cable from the personal computer and from the controller (disconnect the connection).
- Switch on the electrical power supply to the controller first and then the compressed air supply!

Start the movement of the slide with the control panel of the controller (continuous operation)! Stop the movement of the slide with the controller's control panel!

Caution

Danger!
The NC axis may perform movements with high force and at high speed when the compressed air is connected.

6. Remedying an EMERGENCY-STOP situation with the controller control panel

- Start the movement of the slide with the controller's control panel.
- Press the EMERGENCY-STOP button.
- Remedy the EMERGENCY-STOP situation!
- Restart the movement of the slide!

Exercise 5
Diagnosis on a closed-loop-controlled axis

Training aim

- Familiarising yourself with the characteristics of a closed control loop
- To be able to record the movement pattern of an NC axis
- To be able to present the movement pattern of an NC axis graphically

Technical knowledge

Closed control loop
Controller modules, valves, linear unit and measuring system are interconnected in such a manner as to produce a closed control loop (Figure A5.1). This affects

- the movement pattern of the servo-pneumatic NC axis and
- the behaviour of the axis in the event of a fault (e.g. cable discontinuity).

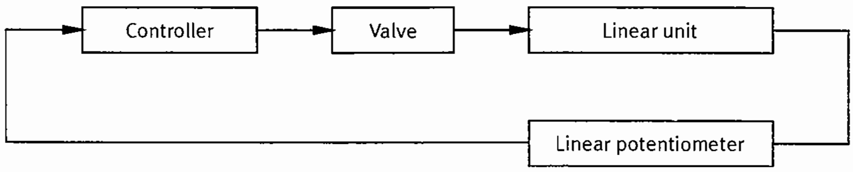


Figure A5.1: Servo-pneumatic linear axis: Signal flow in the closed control loop

Closed control loop elements
Figure A5.2 shows the signal flow in a control loop. A closed control loop consists of four elements:

- Controlling device
- Final control element
- Controlled system
- Measuring device

Each element of the control loop represents a module of the servo-pneumatic axis.

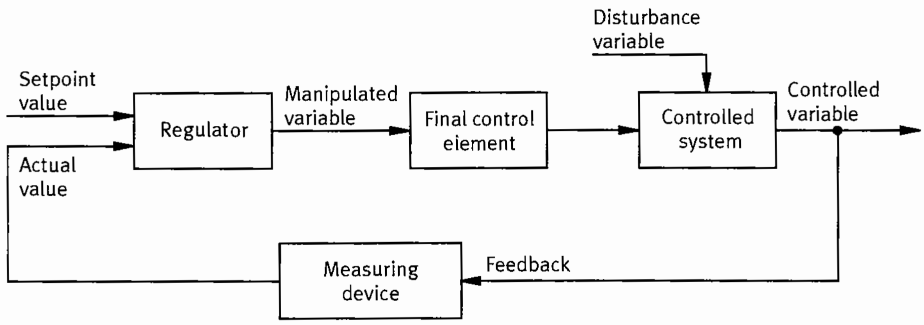


Figure A5.2: Signal flow chart of a closed control loop

Controlling device
The Controller SPC 200 contains the regulator (closed loop controller) for the servo-pneumatic axis in addition to the NC control. The regulator is referred to here as a controller for reasons of simplicity.

Final control element
The proportional directional control valve MPYE-5-1/8 serves as the final control element. It regulates the compressed air flow from and to the cylinder.

Controlled system
The controlled system consists of operating cylinder, guides, slides and load.

Measuring device
The linear potentiometer detects the position of the slide and signals this to the controller. It thus serves as a measuring device.

Characteristics of the closed control loop

Reference variable
The reference variable is available at the start of the control loop. It presets the setpoint value for the controlled variable. The reference variable for the closed control loop of a servo-pneumatic NC axis is the desired position of the slide. It is preset by the NC control.

Controlled variable
The controlled variable is available at the end of the control loop. On a servo-pneumatic axis, the controlled variable is formed by the actual position of the slide.

System deviation
The system deviation is the difference between reference variable and controlled variable. It is computed in the controller. On the servo-pneumatic linear axis, the system deviation corresponds to the deviation between the desired position and actual position.

Manipulated variable
The manipulated variable is computed in the controller on the basis of the system deviation. On the servo-pneumatic NC axis, the manipulated variable acts on the proportional valve. It serves to adjust the valve spool. The valve is set so that the operating cylinder receives the currently required compressed air quantity.

Disturbance variable
Disturbance variables are influences on the controlled system originating from outside the control loop. The movement of the NC axis may be disturbed, for instance, by the fact that dirt accumulates in the bearings and causes the axis to become sluggish.

Feedback
The controlled variable is fed back via the feedback to the controlling device. On the servo-pneumatic axis, the actual position of the slide is signalled via the feedback to the controller.

Features of a closed loop

Closed-loop control system
The course of actions in a control loop is always closed.

Constant detection of the controlled variable
The controlled variable is detected constantly. The measuring device is used for this purpose.

Constantly endeavouring to make the system deviation zero
The current value of the controlled variable is constantly compared with the reference variable. The system deviation is computed on the basis of this. The controller attempts to make this difference zero. Since this is frequently not possible or is very complex owing to disturbance variables, the only requirement in practice is that the system deviation be less than the preset limit value.

Assessment of a control process
The simplest way of assessing the control behaviour is on the basis of a graphic representation of the slide movement. Figure A5.3 shows a graphic representation of reference variable (desired position of the slide), controlled variable (actual position of the slide) and manipulated variable as a function of time.

- At the start, the reference variable (desired position) is 100 mm. The control variable (actual slide position) is also at 100 mm. The standardised manipulated variable is approx. 0, i.e.: the proportional valve is closed.
- The reference variable (desired position) is varied continuously from 100 mm to 400 mm. The manipulated variable is varied and the proportional valve opens.
- Under the influence of the incoming or outgoing compressed air, the actual position follows the desired position. The slide moves to the new target position (400 mm). Major actuating movements of the valve can be seen.
- The valve is adjusted so that the slide stops at position x = 400 mm.
- The slide stops at the new position. The proportional directional control valve is closed (standardised manipulated variable: approx. 0).

A good control behaviour is characterised by the following features:

- The controlled variable follows changes in the reference variable quickly and without overshoot.
- The control is insensitive to disturbance variables (e.g. changes in supply pressure, changes in friction owing to soiling).

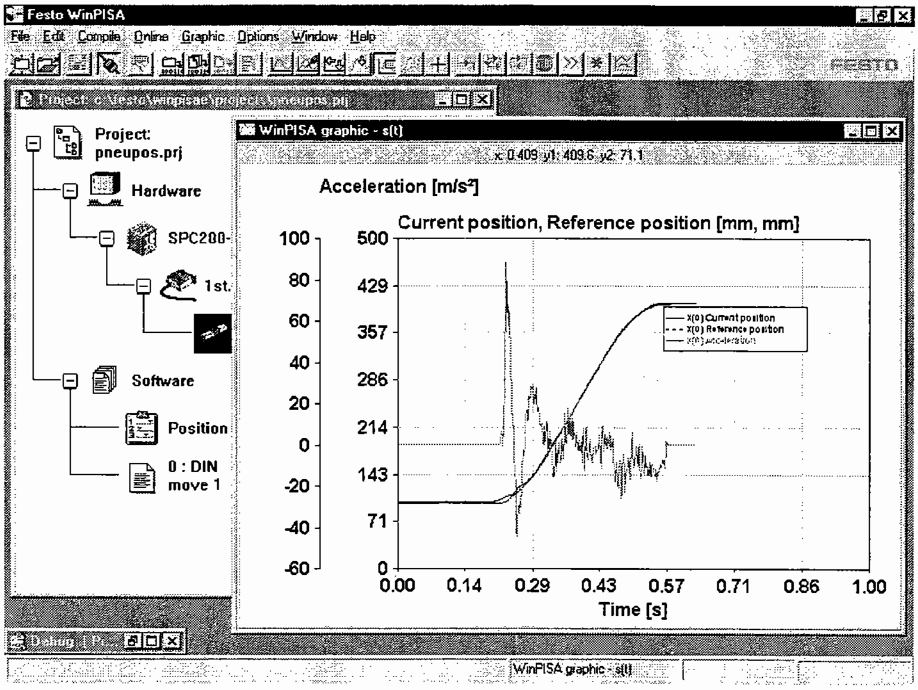


Figure A5.3: Positioning operation: Characteristics of reference variable, controlled variable and manipulated variable

Recording and representing a movement operation
The controller can measure and record various characteristics of the control loop (Figure A5.4), including reference variable (setpoint position), controlled variable (actual position) and manipulated variable (positioning signal).

Measured variables	**Range**	**Unit**	**Description**
Target setpoint value	Position value in the traverse range	mm	End position of the axis for the current traverse command
Actual position	Position value in the traverse range	mm	Actual position of the axis
Speed	Maximum speed	mm/s	Current speed of the axis
Acceleration	Maximum acceleration	mm/s^2	Current acceleration of the axis
Desired position	Position value in the traverse range	mm	Current desired position of the axis computed by the controller
Desired speed	± maximum speed	mm/s	Desired speed computed by the controller
Desired acceleration	± maximum acceleration	mm/s^2	Desired acceleration computed by the controller
Positioning signal	-1 ... +1	–	Standardised valve positioning signal: -1 corresponds to 0 V control voltage +1 corresponds to 10 V control voltage
Motion Complete	0 or 1	–	Shows the end of the current traverse movement corresponding to the defined positioning quality class: 0 Position not (yet) reached 1 Position reached

Figure A5.4: Measurable variables

Recording and representing a movement operation are controlled via WinPISA. The following preconditions must be met:

- The personal computer and the controller must be connected by means of the diagnostic cable.
- The electrical power supply and the compressed air supply must be switched on.
- The project must have been loaded into the controller.
- "Online mode" must have been activated in WinPISA.
- The command sequence for controlling the axes must have been activated (by "Online", "Control Axes", select program 0, confirm warning).

The following steps are required for the procedure:

- Configuring the measurement
- Recording the movement operation in the controller, loading the data into the personal computer
- Graphic display of the movement operation on the screen.

Configuring the measurement
The measurement is configured by clicking on the "Online", "Measurement" and "Configure" buttons.

Then choose the axis (in this case: axis "X") and set the recording cycle. In the case of "1", each value processed in the controller is recorded. This leads to a very precise graphic display. In the case of "10", only every tenth measured value is shown in the graphic. This suffices for this present exercise and means that it does not take long to load the measurement data from the controller to the computer.

Confirm the entry with Ok".

Recording the measured values and loading them into the PC

The measured values are recorded in the following order:

- Click on the NC block with which recording is to commence in the Debug window
- Mark the NC block by "Online", "Measurement", "Set/Delete Start Point"
- Click on the NC block at which measured value acquisition is to end in the Debug window
- Mark the NC block with "Online", Measurement", "Set/Delete Stop Point"
- Choose the NC block with which continuous operation is to commence
- Start continuous operation with "Online", "Control Command", "Start Continuous Operation".

The NC blocks are processed as far as the marked stop point. The measured values are recorded and loaded into the personal computer.

Saving the measurement data

The measurement data must be stored on the hard disk in order to prevent it being lost with the next measurement. This can be done by clicking on buttons "Online", "Measurement", "Save Data", entering a name for the measured value file and clicking on "Ok".

Graphic display (Standard graphic)

The graphics on standard databases allow the positioning behaviour to be assessed quickly. You must choose one of the functions offered under "Graphic", "Standard" in order to activate it. Choose Axis "X" in the sub-menu.

The selected function is displayed in the Graphic window (Figure A5.5).

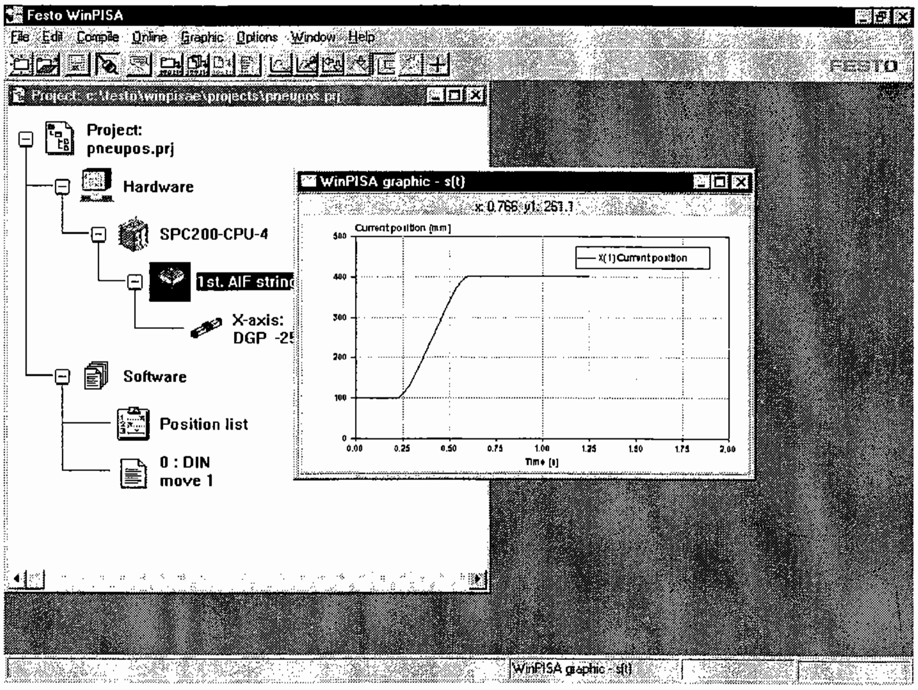


Figure A5.5: Standard graphic: Actual position as a function of time t

Graphic display (user-defined)
The user-defined graphic allows numerous forms of representation. In particular, several curves can be displayed in one diagram.

The example below illustrates the procedure for creating a user-defined graphic. In this example, the setpoint position, actual position and the manipulated variable are shown as a function of time. The following steps are required:

- Choose "Graphic", "New"
- Choose "Open" in the Dialog window, click on the name of the required measured value file (Figure A5.6) and confirm this with "Ok"
- Choose Positioning Axis "X" under Available Measurement Data
- Click on "Time" under Diagram Layout at "x axis" (corresponds to horizontal axis of the graphic)
- Choose measured variable "Positioning Signal" and then click on "y2" under Assign Measurement Data (corresponding to vertical axis of the graphic, 2nd scale)
- Choose measured variable "Setpoint Position", and then click on "y1" (under Assign Measurement Data (corresponds to vertical axis of the graphic, 1st scale)
- Choose measured variable "Actual Position" and then click on "y1" under Assign Measurement Data (same scale as the desired position).
- Click on "OK".

If necessary, any variables which have been wrongly selected can be removed (by clicking on them and clicking on "Delete Curve").

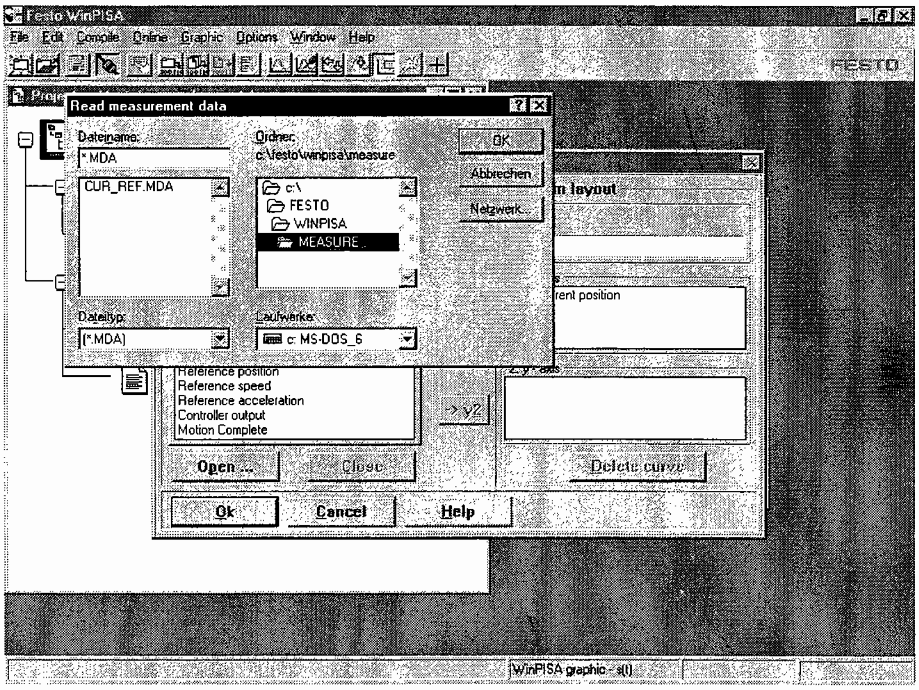


Figure A5.6: Opening a measured value file

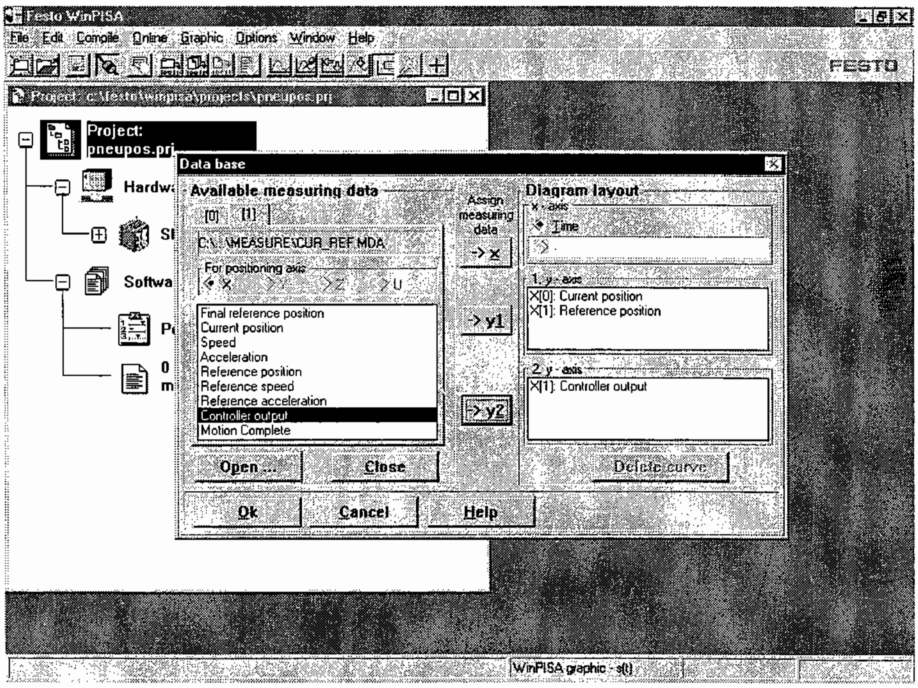


Figure A5.7: Selecting the measurable variables for the graphic display

Problem description

A handling device transfers jars to a crate. The device has been put into operation. When this was done, vibrations occurred so that some of the jars were damaged. The movement behaviour of the axis is to be documented by means of a graphic representation.

Positional sketch

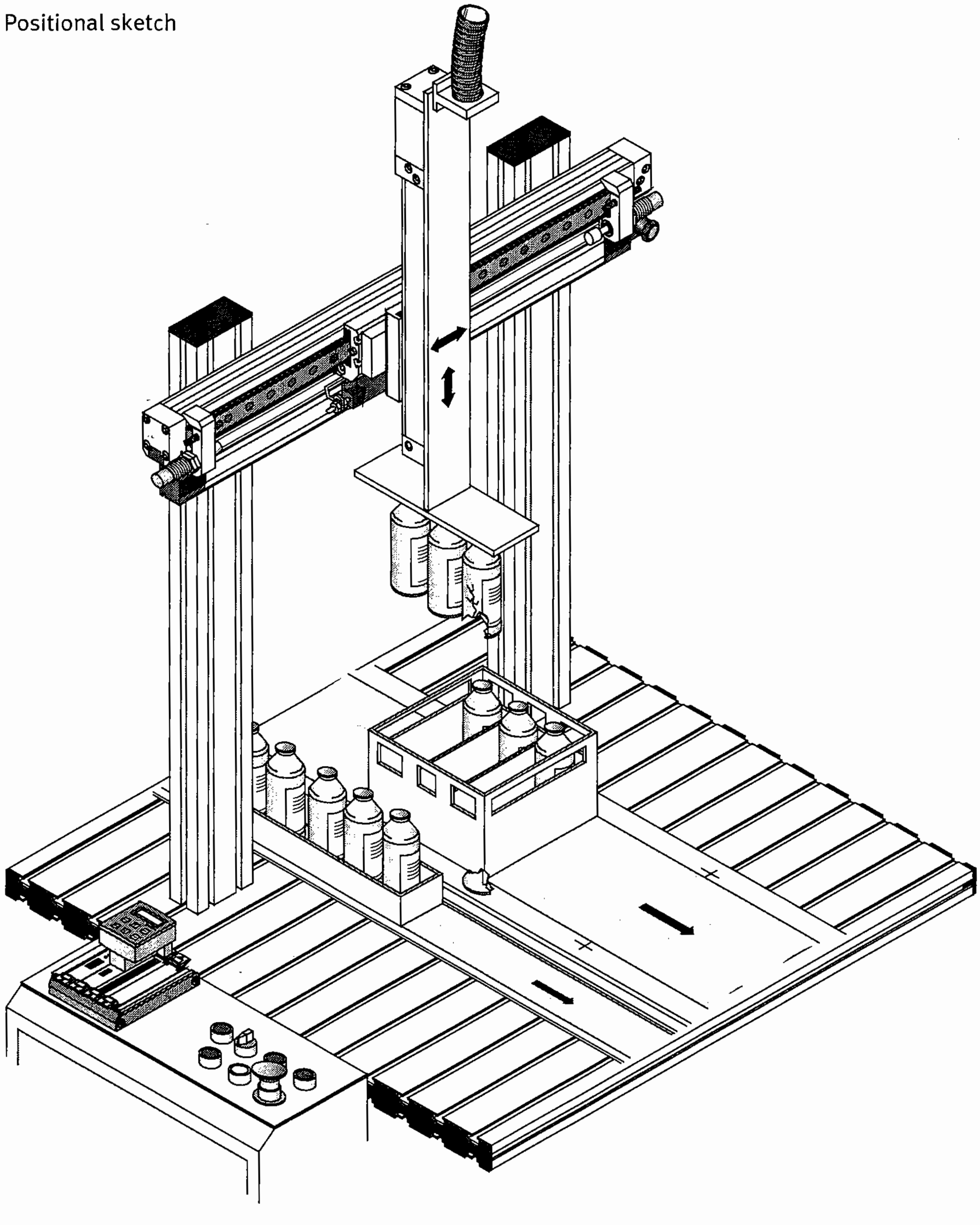


Figure A5.8: Positional sketch of the handling device

Problem definition

- Naming the elements and characteristics of a closed control loop
- Recording measured values
- Graphically representing a movement operation

Procedure

1. Adding signal flow charts

Enter the elements and characteristics of a closed control loop in the block diagram!

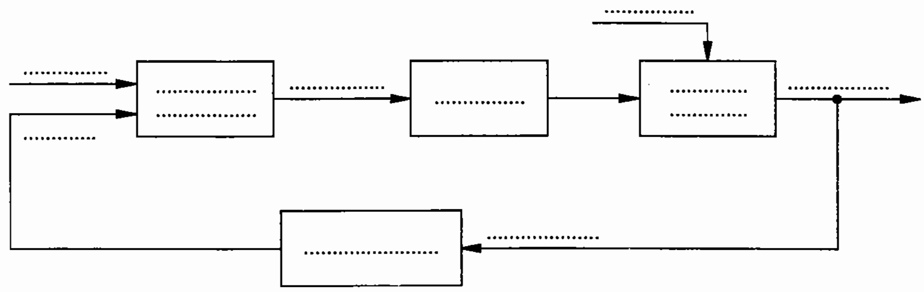


Figure A5.9: Elements and characteristics of a closed control loop

Consider what modules of the servo-pneumatic axis correspond to the elements of the closed control loop. Enter the modules and the physical variables in the block diagram!

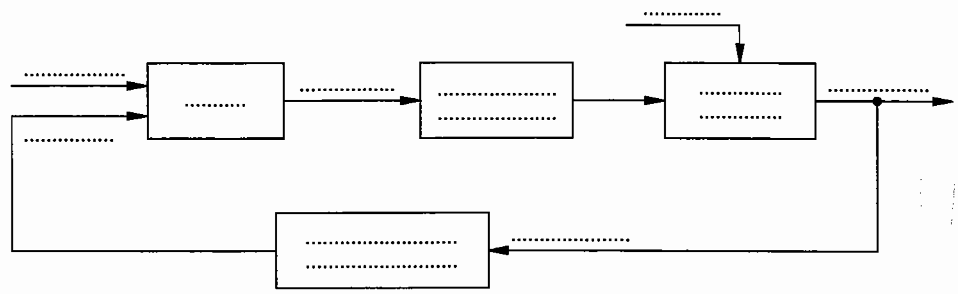


Figure A5.10: Closed control loop with modules of a servo-pneumatic axis

2. Creating a new project

- Open a new project of name "Handev" in WinPISA.
- Configure the axis in accordance with Exercise 3.

3. Writing and testing a new program
The following boundary conditions must be met:

- The pick-up position for the jars is x = 70 mm.
- The deposit positions 1, 2, 3 and 4 are located at 200, 270, 340 and 410 mm.
- The slide should wait 1.5 seconds at each position.
- The movements should be performed at maximum speed.

Design an NC program which produces the movement operation demanded in the problem description.

Enter the program. Conduct the syntax check and compile the project.
Remedy any faults.

Test the function of the program! Compare the motion sequence with the requirements. Remedy any faults!

4. Recording and loading the measured values
Record the following movement operation:
The slide of the NC axis moves from the pick-up position to deposit position 1 and back to the pick-up position.

Proceed as described in Section "Technical knowledge"!

5. Representing the measured values
Create the following graphics:

- Actual position as a function of time (standard graphic)
- Setpoint position, actual position and manipulated variable as a function of time

Proceed as described in Section "Technical knowledge".

Exercise 6
Handling sensitive goods

Training objective

- Familiarising yourself with safety circuits
- To be able to select appropriate EMERGENCY-STOP circuitry
- To be able to check EMERGENCY-STOP behaviour in practice

Technical knowledge

Requirements applicable to the behaviour in the case of EMERGENCY-STOP
EMERGENCY-STOP devices serve to protect systems and operators in danger situations.

The following requirements must be followed when implementing the EMERGENCY-STOP function:

- The EMERGENCY-STOP button must be fitted at an easily accessible point.
- The EMERGENCY-STOP button must comply with the relevant standards (red button on a yellow background, button to detent after it has been actuated).
- Several EMERGENCY-STOP buttons must be fitted on larger installations.
- If the EMERGENCY-STOP is actuated, no unforeseeable movements of the system may occur. Operators should not be put in danger.
- On actuation of the EMERGENCY-STOP, the system must be brought to a safety position.
- On actuation of the EMERGENCY-STOP, the system must be disconnected as far as possible from the electrical and pneumatic power supply.
- After release of the EMERGENCY-STOP button, the system may not restart.

Electrical implementation of the EMERGENCY-STOP function
The EMERGENCY-STOP function must be implemented so that, in the event of failure of the electrical power supply, the system assumes the safety position. Each EMERGENCY-STOP button must consequently be designed as a normally closed contact.

Figure A6.1 shows the electrical EMERGENCY-STOP circuitry for control of the servo-pneumatic NC axis. The EMERGENCY-STOP button interrupts the supply voltage for the load circuit. The power supply to the controller itself is retained when the EMERGENCY-STOP button is pressed..

Electrical connection diagram

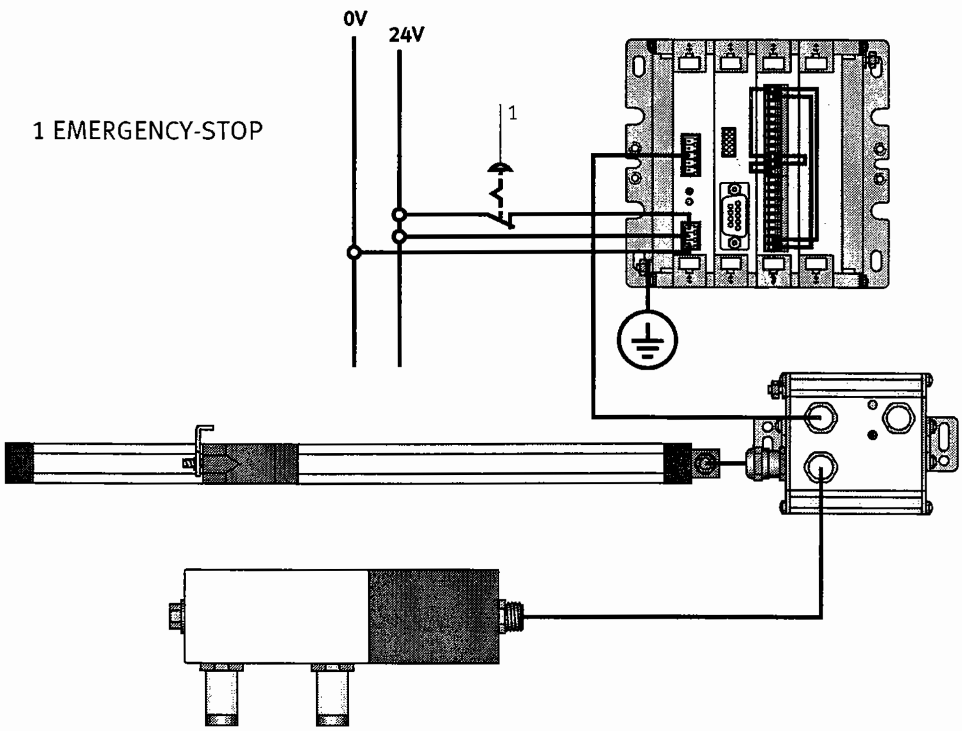


Figure A6.1: EMERGENCY-STOP: Electrical circuitry of the NC axis

Pneumatic implementation of the EMERGENCY-STOP function

Switching valves (Figures A6.3 to A6.6) are inserted between proportional valves and cylinder in order to ensure a clear behaviour of the NC axis in the event of failure of the electrical power supply or if the EMERGENCY-STOP is actuated. In the event of a fault, these valves ensure that a defined pressure level is set in the chambers of the cylinder resp. that the cylinder chambers are shut off.

All four circuits have the following features in common:

- In normal operation, the three switching valves 0V1, 1V2 and 1V3 are actuated. Ports 2 and 4 of the proportional valve are connected to the two chambers of the double-acting cylinder. The axis is controlled with a 5/3-way proportional valve.
- In the event of EMERGENCY-STOP resp. in the event of failure of the electrical power supply, valves 0V1, 1V2 and 1V3 revert to neutral position. The proportional valve is disconnected from the cylinder chambers.

The circuitry of port 3 of valves 1V2 and 1V3 must be selected so that the required behaviour occurs in the event of EMERGENCY-STOP (Figure A6.2).

Behaviour of the cylinder	Port 3 of valve 1V2	Port 3 of valve 1V3
Cylinder depressurised	Connect silencer	Connect silencer
Piston clamped	Close with plug	Close with plug
Right end position	Connect compressed air	Connect flow control valve with silencer
Left end position	Connect flow control valve with silencer	Connect compressed air

Figure A6.2: Pneumatic circuitry and EMERGENCY-STOP behaviour

EMERGENCY-STOP: Exhausting cylinder chambers

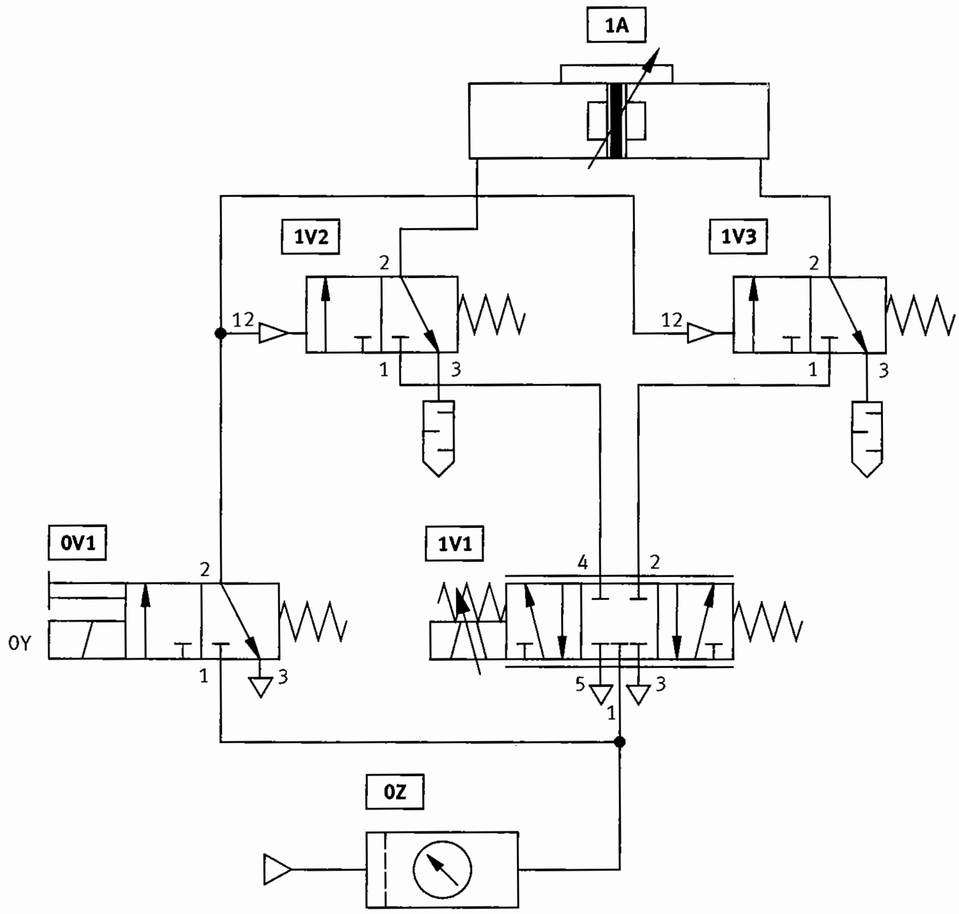
Both cylinder chambers are exhausted in the case of EMERGENCY-STOP (Figure A6.3). This results in the following behaviour:

- Piston and slide are decelerated.
- After completion of the deceleration operation, piston and slide are held only by friction, i.e. with only a slight force.

This circuit is primarily used for horizontally fitted axes. In the case of unfavourable boundary conditions (high traversing speed, high load), the stopping distance is longer. If the slide is also just in front of an end position when the EMERGENCY-STOP is actuated, it may contact a stop.

This circuit variant is unsuitable for a vertical arrangement of the axis since the retention force is inadequate. In the case of an EMERGENCY-STOP, this may lead to an uncontrolled downward movement of the slide resp. the axis body.

Circuit diagram, pneumatic



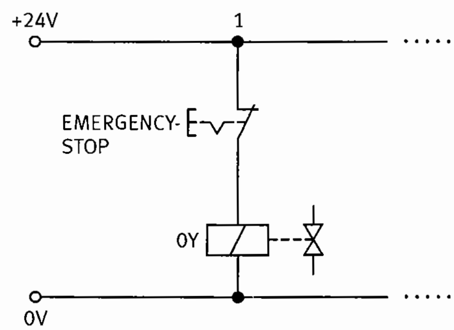


Figure A6.3: Exhausting the cylinder chambers in the case of an EMERGENCY-STOP

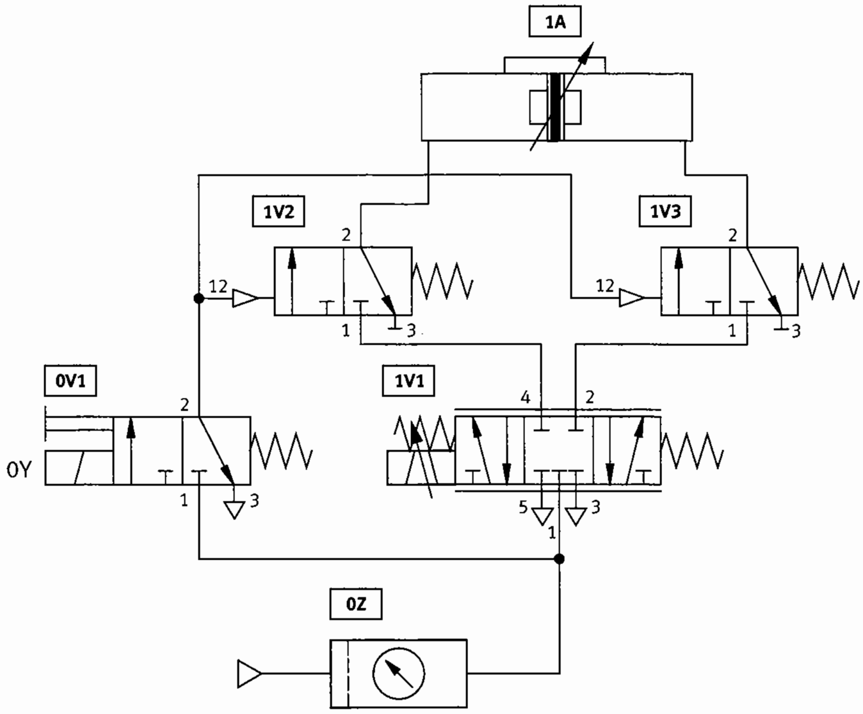
EMERGENCY-STOP: Pneumatically clamping the piston

If both chambers are shut off in the case of an EMERGENCY-STOP (Figure A6.4), this leads to the following behaviour:

- The piston is decelerated comparatively hard
- The piston is held in its position by friction and by clamping between both air columns after completion of the deceleration operation.

This circuit variant is suitable for horizontal, vertical and inclined installation position of the axis.

Circuit diagram, pneumatic



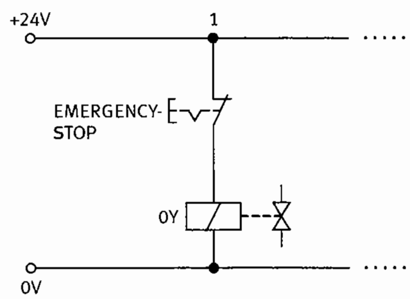
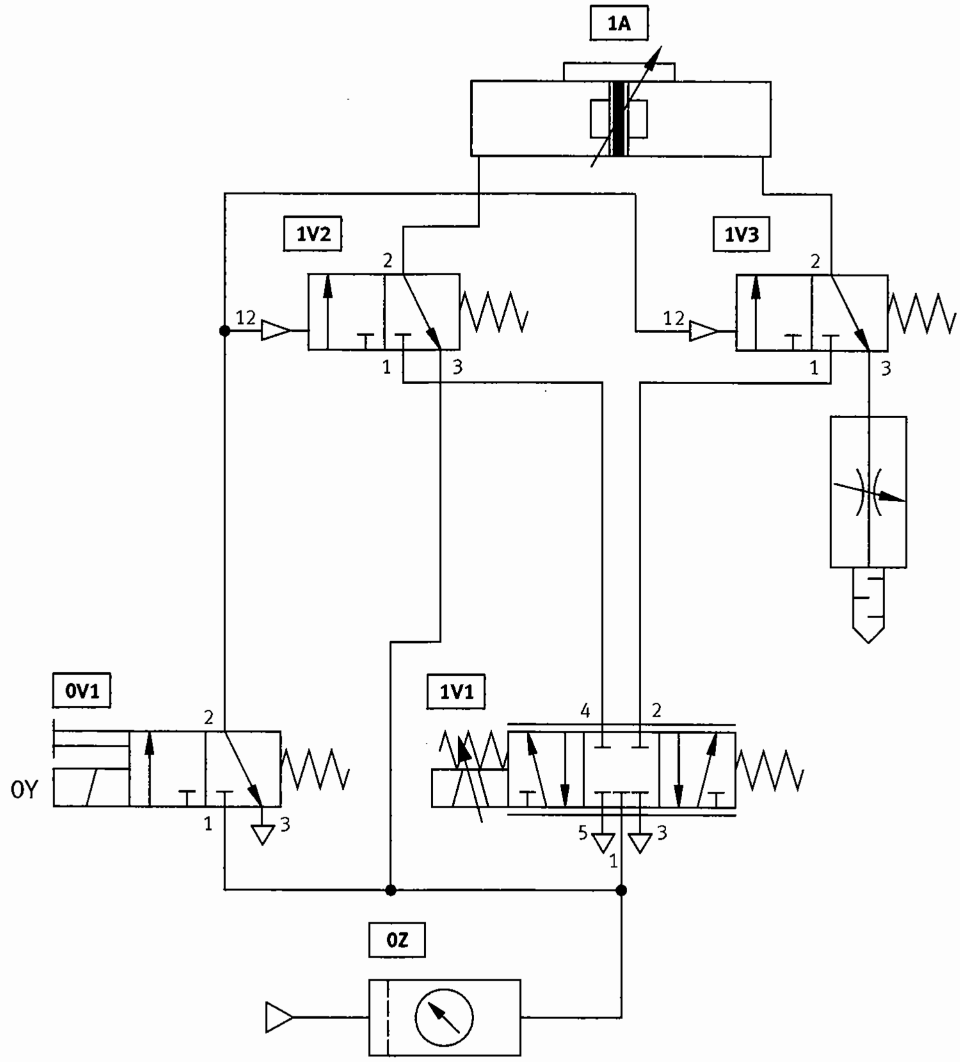


Figure A6.4: Clamping of the piston in the case of an EMERGENCY-STOP

EMERGENCY-STOP: Moving piston to stop
Piston and slide are moved to a stop for EMERGENCY-STOP in the case of both circuit variants (Figures A6.5, A6.6). The impact energy is all the higher, the greater the moving mass and the higher the impact velocity is. The stop must be secured in position accordingly, e.g. by using a shock absorber that absorbs the impact energy. In addition, it may be useful to reduce the impact velocity by exhaust air flow control.

The option of moving the piston and slide against the stop in the case of EMERGENCY-STOP is used preferably
- in the case of vertical installation position
- on axes whose slide is permanently mounted and whose axis body moves. The axis body is retracted in the case of an EMERGENCY-STOP in order to avoid damage resulting from collision.

Circuit diagram, pneumatic



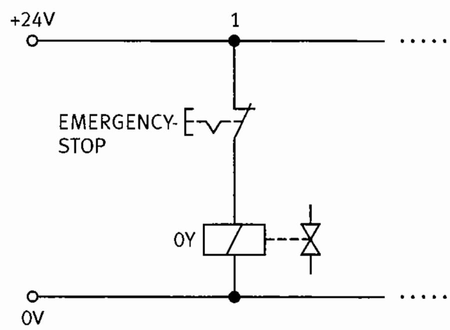
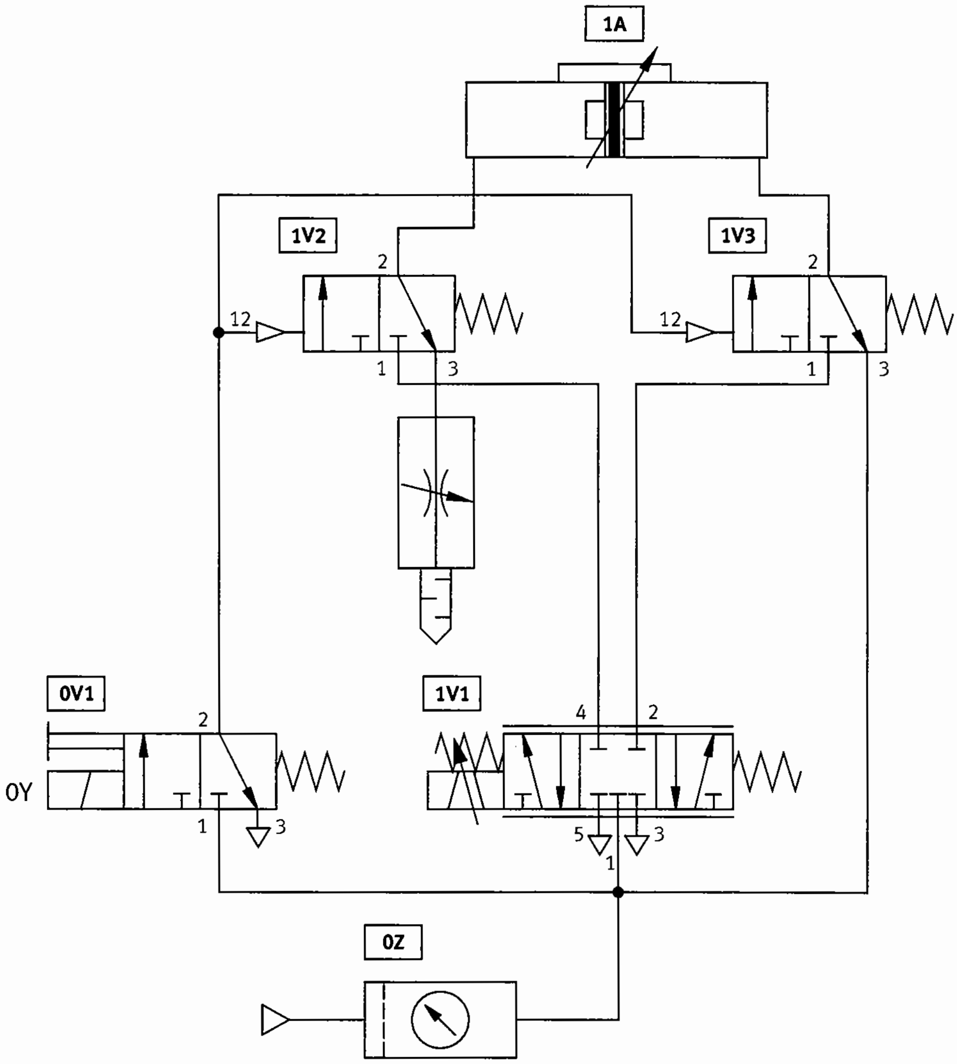


Figure A6.5: Piston moves to right hand stop in the case of EMERGENCY-STOP

Circuit diagram, pneumatic



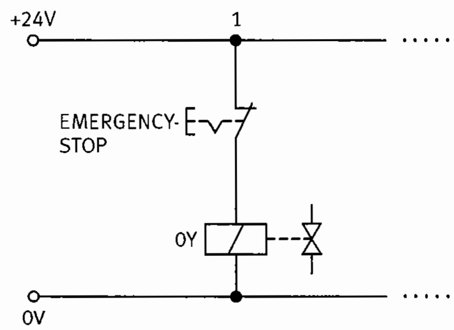


Figure A6.6: Piston moves to left hand stop in the case of EMERGENCY-STOP

Problem description

Jars are transported using a handling device. The related pneumatic EMERGENCY-STOP circuitry is to be planned, implemented and tested. It must be designed so that the jars transported and the handling device are not damaged wherever possible on actuation of the EMERGENCY-STOP.

Positional sketch

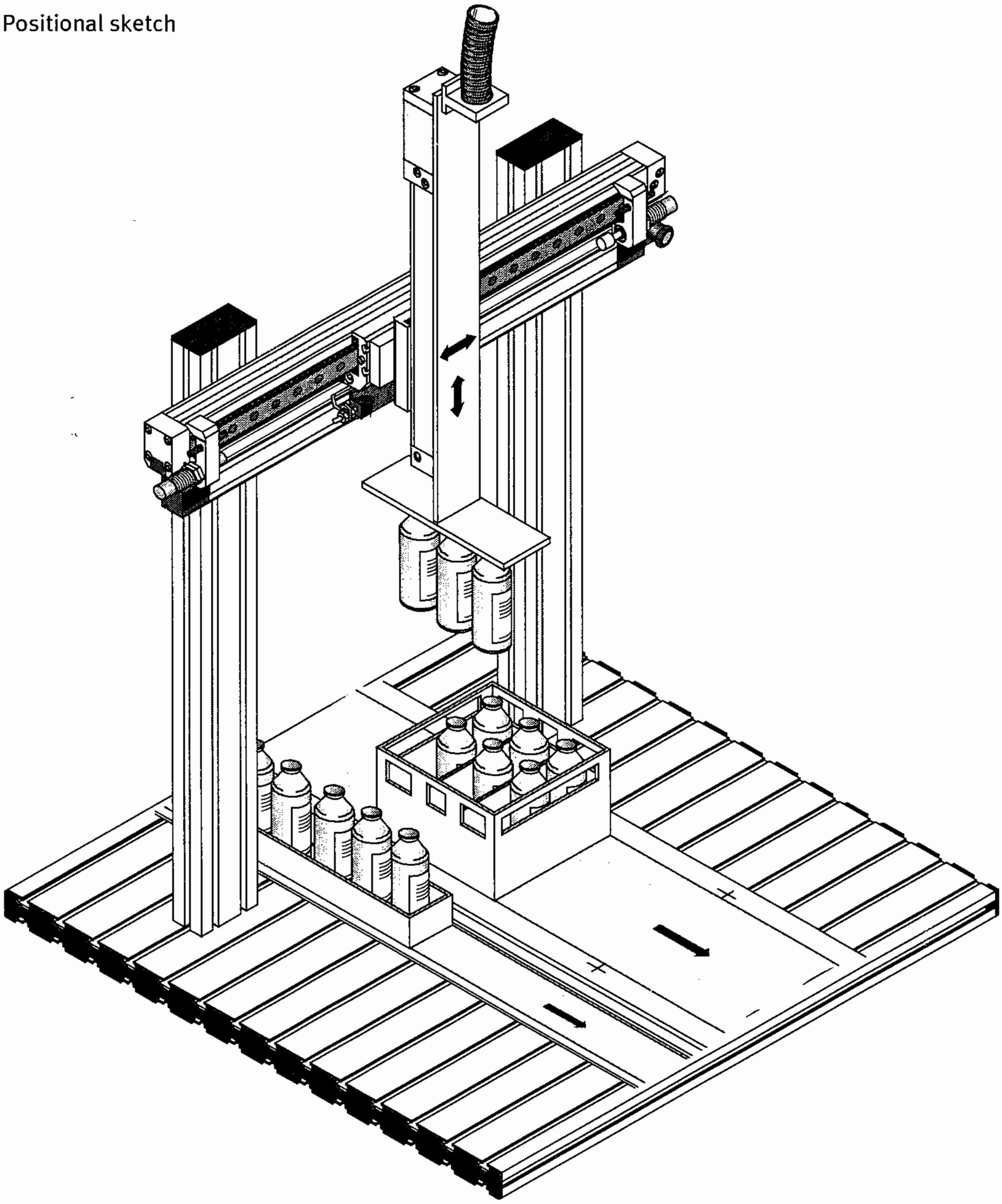


Figure A6.7: Positional sketch of the handling device

Problem definition

- Selecting a suitable EMERGENCY-STOP circuit
- Setting up the EMERGENCY-STOP circuit
- Testing the function of the EMERGENCY-STOP circuit
- Comparing the behaviour of different EMERGENCY-STOP circuits

Procedure

1. Creating and testing the project and program
The same project and program are used as in Exercise 5 (Project "Handev").

If you have not yet worked through Exercise 5, you must first write and test the project and program (exercise points 2 and 3 of Exercise 5).

2. Selecting a suitable pneumatic circuit for the EMERGENCY-STOP function

- Select a suitable pneumatic circuit for implementing the EMERGENCY-STOP function!
- Substantiate your choice!
- Sketch the circuit diagram!

3. Setting up and testing an EMERGENCY-STOP circuit (cylinder chamber depressurised)

Caution
Switch off the compressed air supply before you start converting the tubing connections!

Set up the pneumatic circuit shown in Figure A6.3!
Test the function of the system when the EMERGENCY-STOP button is not pressed!
Test the function on actuation of the EMERGENCY-STOP button!
Press the EMERGENCY-STOP button in different phases of the movement cycle!
Does the effect of the EMERGENCY-STOP button meet your expectations?

4. Setting up and testing an EMERGENCY-STOP circuit (piston clamped)

Caution
Disconnect the compressed air supply!

Set up the pneumatic circuit shown in Figure A6.4.
Test the function of the system when the EMERGENCY-STOP button is not pressed!
Test the function on actuation of the EMERGENCY-STOP button!
Press the EMERGENCY-STOP button in different phases of the movement cycle!
Does the effect of the EMERGENCY-STOP button meet your expectations?

5. Comparison of the behaviour of different EMERGENCY-STOP circuitry types
Which of the two circuits (Figures A6.3 resp. A6.4) shows the better behaviour on actuation of the EMERGENCY-STOP?

Exercise 7
Setting up a gantry system using servo-pneumatic drives

Training aim

- To be able to mechanically set up a twin-axis gantry system
- To be able to make the tubing connections to the system
- To be able to wire the system
- To be able to prepare the system for commissioning

Technical knowledge

Modules of a servo-pneumatic axis

The twin-axis gantry comprises the following mechanical components (Figure A7.1):

- a sub-base
- two columns secured to the sub-base by means of brackets
- a servo-pneumatic NC axis mounted on the columns (direction of movement horizontal, stroke: 450 mm)
- a second servo-pneumatic NC axis whose slide is mounted on the slide of the horizontal axis (direction of movement vertical, stroke: 225 mm)

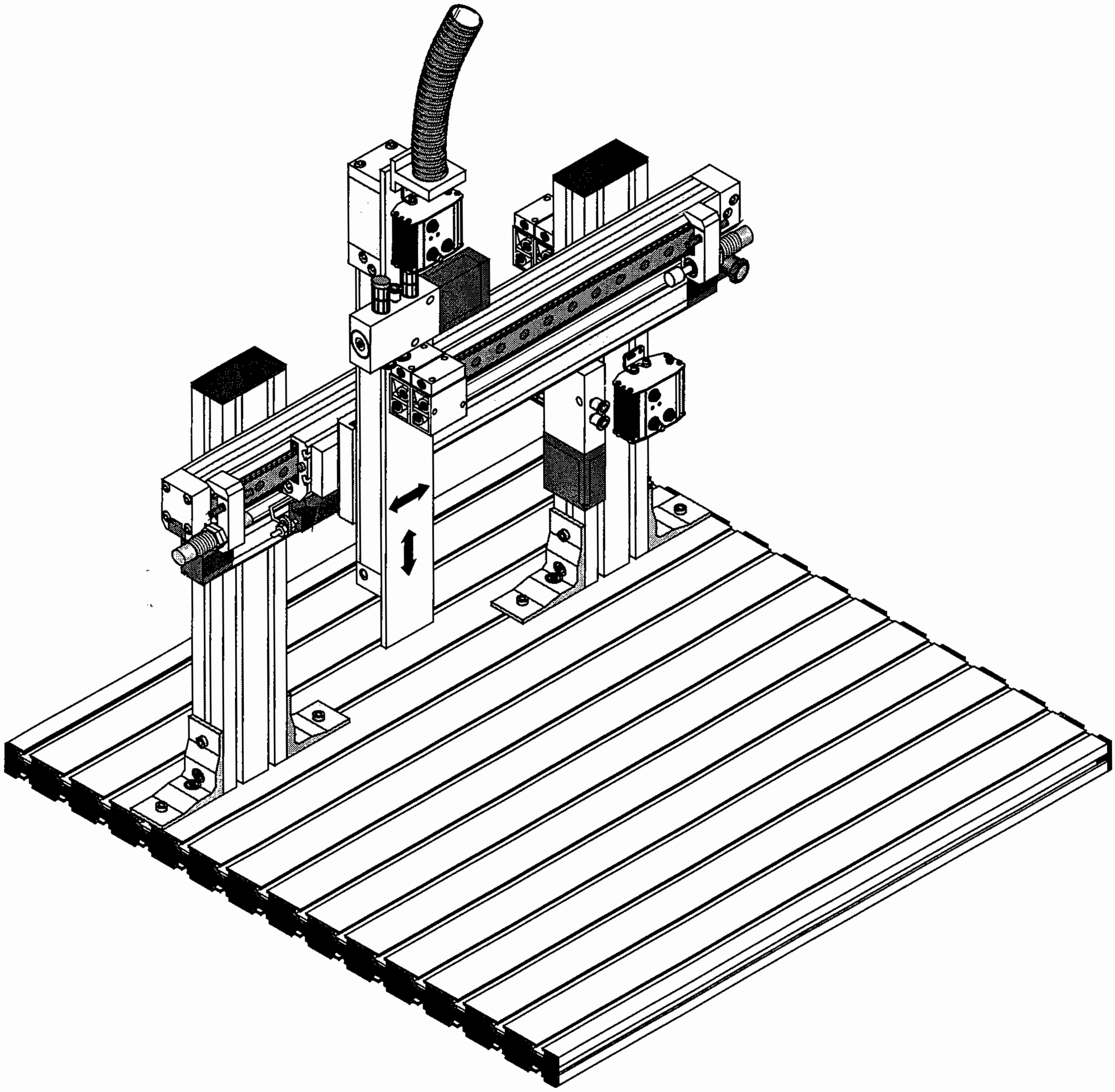


Figure A7.1: Set-up of the twin-axis gantry

Mechanical components

A double-acting slotted cylinder is used as the drive on both axes. Slide, cylinder and guide are each combined to form one linear unit.

Mechanical safety devices
During operation of the system, the slides of both axes are positioned by the closed-loop control system. Additional shock absorbers serve to prevent damage to the cylinders in the event of malfunctions.

Two shock absorbers are mounted on each of the two axes. The shock absorbers must be fitted so that the movement area of the slides is not unnecessarily restricted.

Safety information
High acceleration and deceleration forces occur owing to high cylinder forces and high moving mass. All mounting screws must thus be tightened particularly carefully.

Servo-pneumatic drive: Pneumatic circuit diagram
Each of the two axes features a servo-pneumatic drive with 5/3-way proportional valve. Figure A7.2 shows the pneumatic circuit diagram of a servo-pneumatic drive.

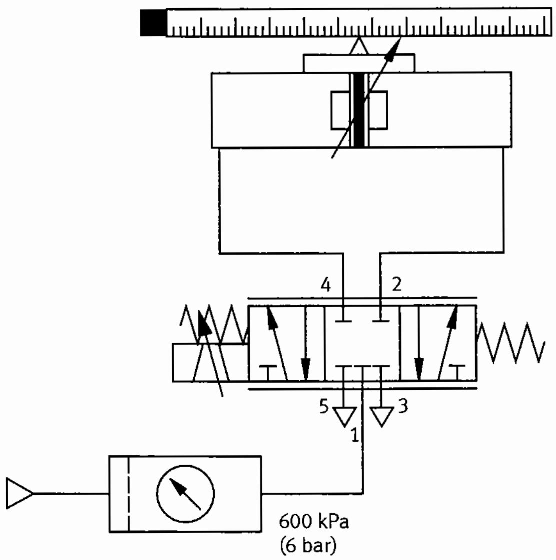


Figure A7.2: Pneumatic circuit diagram of a servo-pneumatic drive

Gantry: Pneumatic circuit diagram

The components of the pneumatic circuit (Figure A7.3) have the following tasks:

- Proportional valves: these operate in normal mode
- Switching valves: these guarantee safe behaviour in the case of an EMERGENCY-STOP

The function of the circuit is explained more precisely in Exercise 8.

Circuit diagram, pneumatic

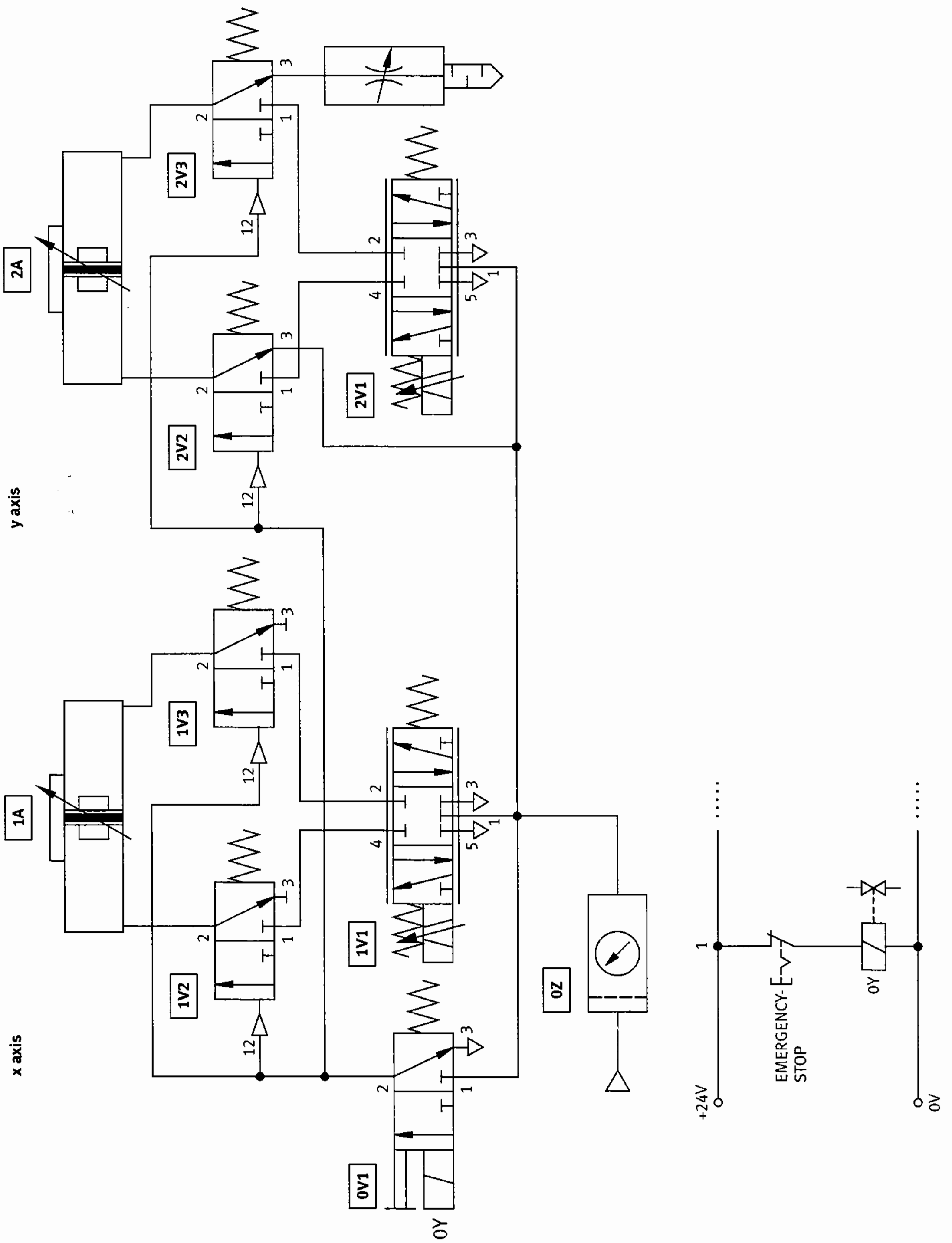


Figure A7.3: Pneumatic circuit diagram of a twin-axis gantry (with switching valves for EMERGENCY-STOP function)

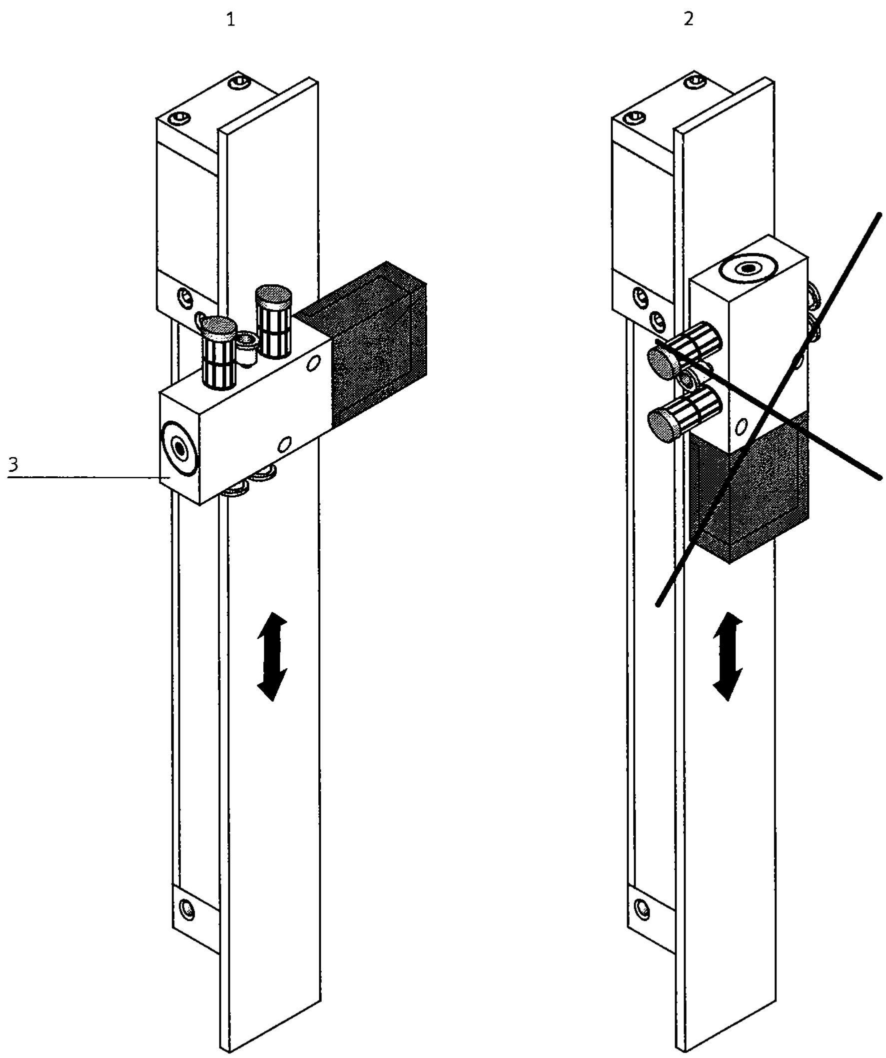
Arrangement of the pneumatic components

The pneumatic components are arranged as follows:

- Electrically actuated switching valve for the EMERGENCY-STOP function: mounted on the sub-base
- Proportional valve for horizontal axis: mounted on one of the two columns of the gantry (on the side of the air port of the cylinder)
- Pneumatically actuated switching valves for horizontal axis: mounted on the same column as the proportional valve
- Proportional valve for horizontal axis: mounted on the axis body (cylinder)
- Pneumatically actuated switching valves for horizontal axis: mounted on the mounting plate of the horizontal axis

Caution

If the proportional directional control valve for the vertical axis is mounted in such a manner that valve spool and cylinder move in the same direction, this may mean retroactive effects. This will impair the control quality of the axis. Consequently, the valve must be attached transversely to the direction of movement of the vertical axis (Figure A7.4).



1 Mounting transverse to the direction of movement
2 Not permitted
3 Proportional directional-control valve MPYE-...

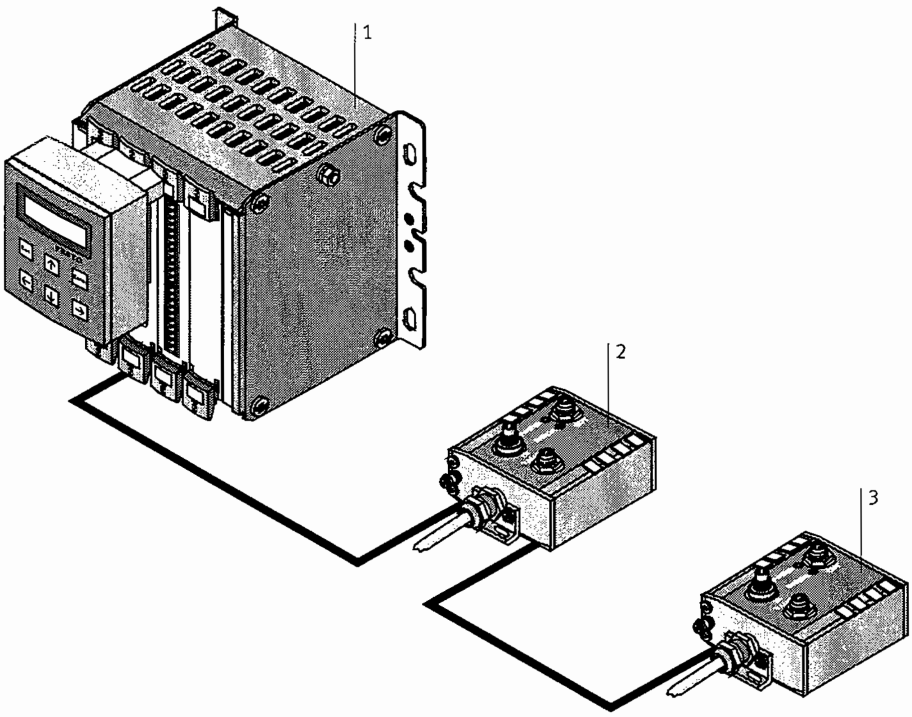
Figure A7.4: Mounting the proportional valve for the vertical axis

Open-loop and closed-loop control

Controller SPC 200 allows open-loop and closed-loop control of two pneumatic NC axes. The following components are required for the twin-axis gantry:

- Controller SPC 200
- Control panel
- Axis interface for horizontal axis (with dark cable and black plug)
- Axis interface for vertical axis (with light cable)

Modules of the controller



1 Controller
2 Axis interface of the x axis (horizontal axis)
3 Axis interface of the y axis (vertical axis)

Figure A7.5: Controller modules for a twin-axis application

Displacement measuring systems

Each of the two axes operates in a closed loop and features a displacement measuring system. The following measuring systems are used:

- Horizontal axis: Potentiometric displacement measuring system
- Vertical axis: Ultrasonic displacement measuring system (Temposonic)

The potentiometer is fitted next to the cylinder. The slide of the potentiometer is connected to the slide of the axis by means of a driver. The ultrasonic measuring system is integrated in the cylinder. It thus requires less space.

Electrical components (EMERGENCY-STOP function).

The EMERGENCY-STOP button serves to stop the system in the event of danger. It must be attached at an easily accessible point.

Connection diagram, electrical

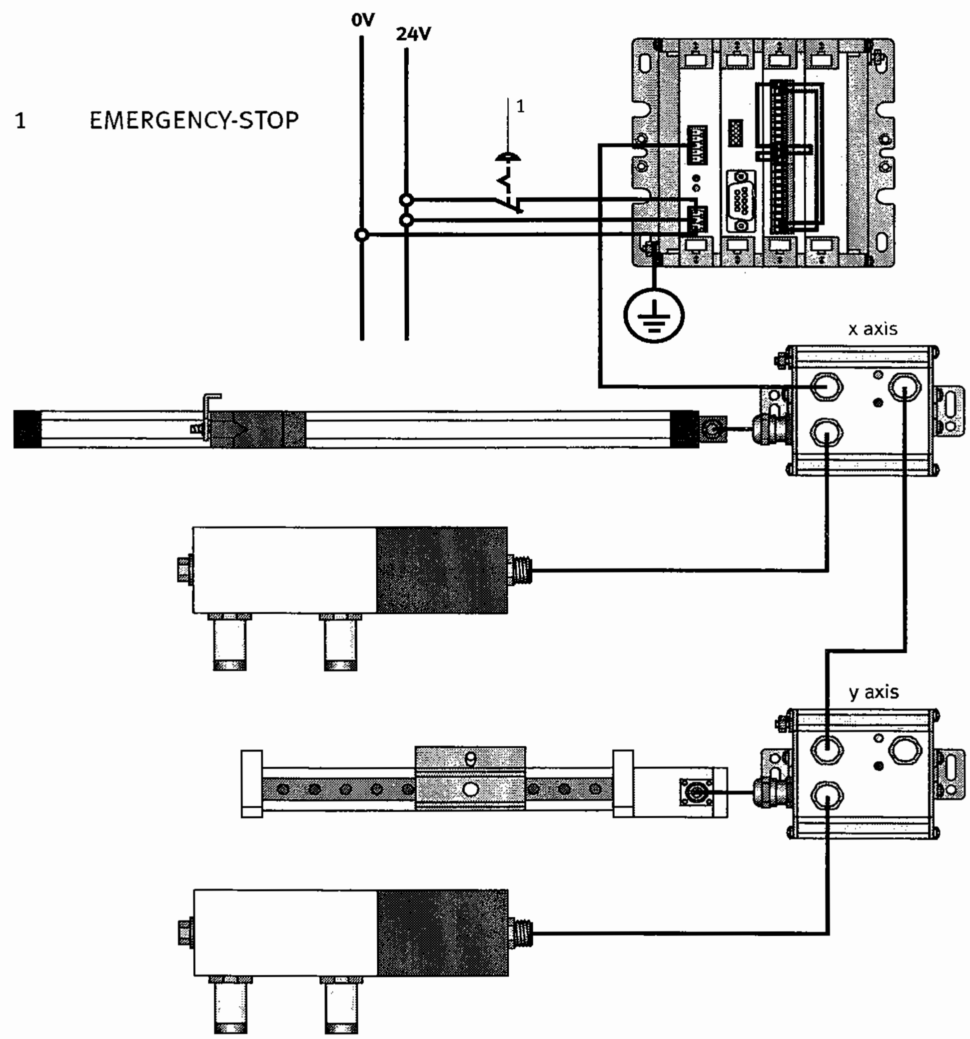


Figure A7.6: Electrical circuit diagram (controller, axis interfaces, displacement measuring systems, proportional valves, EMERGENCY-STOP button, electrically actuated directional control valve)

Arrangement of the electrical components

The components of the electrical circuit must be attached as follows:

- EMERGENCY-STOP button: on the sub-base (at an easily accessible point!)
- Controller: on the outer side of a gantry column (outside of the motion space of axes, cables and tubing; ensure good accessibility of the control panel!)
- Axis interface, horizontal axis: on the same column as the controller, not projecting into the traversing area of the axis.
- Axis interface, vertical axis: on the mounting plate of the vertical axis.

Accessories

The accessories required for setting up the system are included with the equipment set. Either use of the parts is described in the assembly instructions or it results from the set-up of the electrical and pneumatic circuit.

Safety measure

Keep well away from the traversing area of the slide during operation of the system; risk of injury!

Problem description

All components of a gantry system with two servo-pneumatic axes have been delivered. A location has been prepared for setting up the system. It is now the task of the fitter to set up the system professionally on site.

Positional sketch

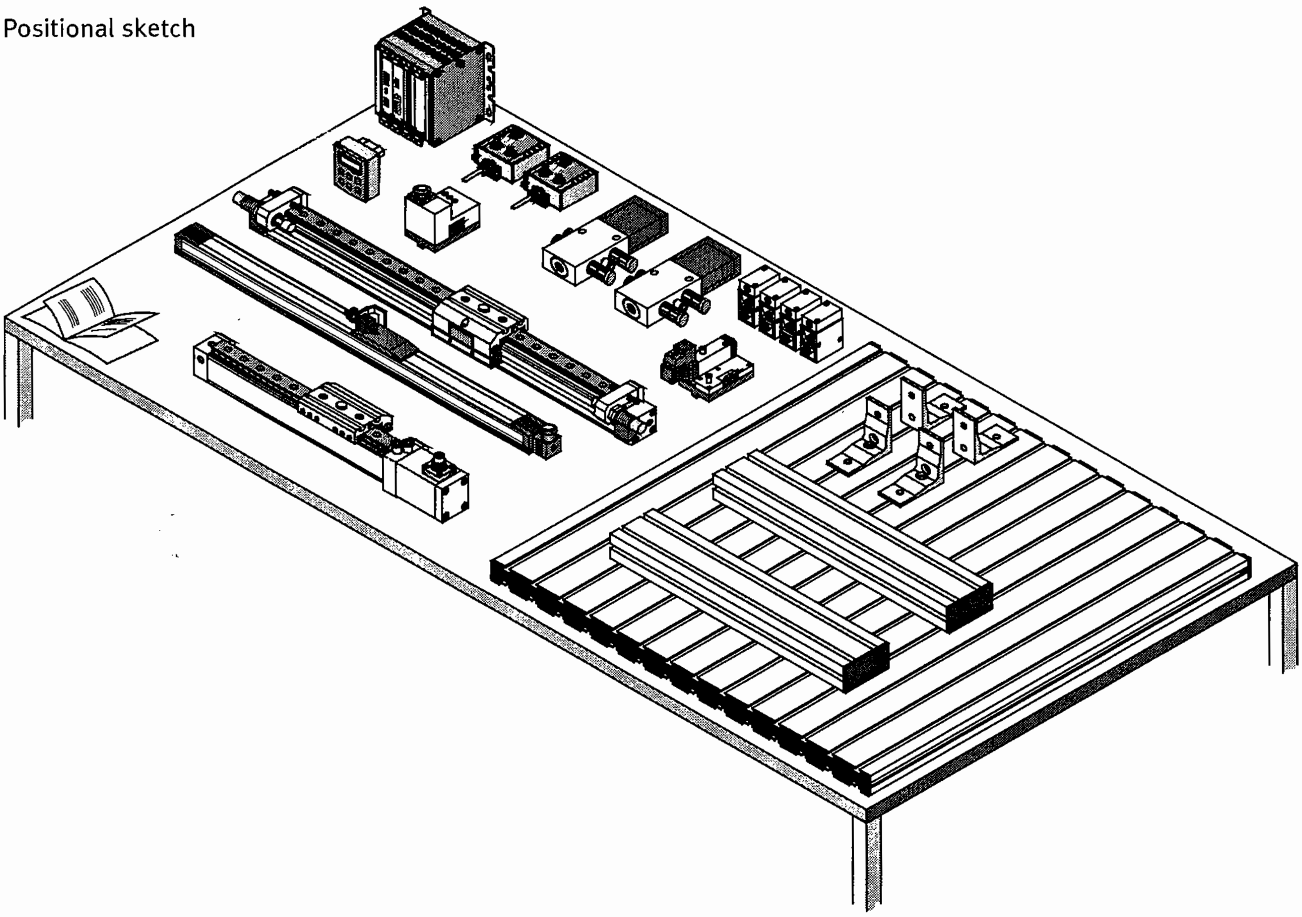


Figure A7.7: Delivered components of the gantry

Problem definition

- Assembling the equipment
- Setting up the pneumatic circuit
- Setting up the electrical circuit
- Checking the overall set-up

Procedure

1. Assembling the measuring system (horizontal axis with 450 mm stroke)
The potentiometer must be fitted to the linear unit using the supplied mounting components. The slide must be slid once manually from one end to the other in order to align the measuring system with the working stroke. If both end positions of the cylinder can be reached without the measuring system reaching its stops, the measuring system is correctly positioned and can be definitively secured.

2. Attaching the shock absorbers
Attach the shock absorbers to the two linear units. The following requirements must be met:

- They must be fitted as far out as possible in order not to unnecessarily restrict the movement area of the slides.
- They must be fitted in accordance with the assembly instructions for the shock absorbers.

3. Drawing a positional sketch
When drawing the positional sketch, note the information on arrangement of the electrical and pneumatic components in the section "Technical knowledge". Also note the following points:

- The control panel of the controller must be attached at an easily accessible point. The display must be easily readable.
- You must be able to operate the EMERGENCY-STOP button easily.
- You must be able to observe axes and valves.
- It must be possible to easily monitor mains voltage and supply pressure.
- Operators must be prevented from intentionally being in the traversing area of the linear unit (risk of injury).
- None of the equipment items may project into the traversing area of the axes.

4. Mechanical set-up
Set up the system mechanically in accordance with the positional sketch using the available accessory parts. Please proceed in the following order:

- Mount the columns on the sub-base.
- Tilt the system so that the columns lie flat on the bench.
- Fit the horizontal axis in this position. Note that the distance between axis and sub-base must be sufficient so as to prevent the vertical axis contacting in the bottom position!
- Move the system to normal position (columns vertical).
- Fit the vertical axis by screwing the slides of both axes together.

Check whether the axes can be moved without hitting the stop by sliding the two slides. Correct the arrangement if necessary!

5. Set-up of the pneumatic circuit
Fit the valves.

Caution

Note the information on installation of the proportional directional control valve for the vertical axis (Figure A7.4).

The tubing connections must be made in accordance with the pneumatic circuit diagram. Please follow the safety information!

Safety information

1. Please ensure when laying the tubing that it does not project into the traversing area of the two axes.
2. The tubing routed from the sub-base to the vertical linear axis must be adequately long. Even in the extreme positions of the two axes, the tubing must not be taut or kinked.

Check the tubing layout by moving both axes by hand to the stop positions. If necessary, correct the arrangement.

6. Setting up the electrical circuit
The electrical interconnection must be made in accordance with the connection diagram (Figure A7.6). Plug on the controller control panel. Use the Festo Didactic 24 V power pack as the power supply.

Check whether both axes can be slid by hand as far as the stop positions. If one or more cables are too short, you must correct the arrangement of the axis interface and/or valves in question.

Caution

None of the cables may be routed in the traversing area of the gantry!

7. Routing of cable and tubing
One cable and two tubing lines are routed from the sub-base to the moving part of the second axis. The supplied split conduit must be placed around cable and compressed air tubing in order to protect them.
The split conduit must neither chafe against or knock other equipment when the axes move. Check this by sliding the slide of both axes by hand!

8. Securing the gantry
In the exercises that follow, both axes are traversed with high force and at high speed. Consequently, the slotted assembly board must be firmly clamped or screwed to a sturdy base!

9. Checking the set-up

- Does the arrangement correspond to the positional sketch?
- Are all screws firmly tightened?
- Can the slides of both axes be slid manually between the stop positions preset by the shock absorbers?
- Can the vertical axis be slid as far as the bottom stop without striking it?
- Slide the vertical axis to the bottom stop position. Can the horizontal axis be moved throughout the entire movement range without the vertical axis colliding with the components secured to the sub-base?
- Is all tubing firmly attached?
- Are all plugs firmly attached?
- Can both axes be slid to the stop positions without the cables or tubing being taut or kinked?
- Ensure that there are no lines or tubing crosswise across the linear unit (risk of shearing off)
- Do the circuits correspond to the circuit diagrams?
- Is the controller with control panel easily accessible?
- Can you easily monitor the supply pressure and supply voltage?
- Is the sub-base attached securely to the base?

Caution

The system is not switched on until the next exercise!

Exercise 8
Commissioning a twin-axis gantry

Training aim

- To be able to commission a twin-axis gantry system
- To be able to check the control direction of the servo-pneumatic linear axes
- To be able to check the EMERGENCY-STOP behaviour of the axes.

Technical knowledge

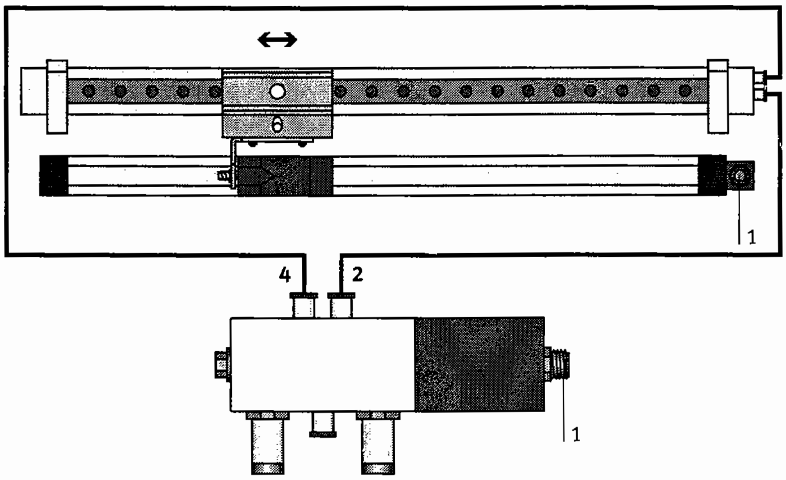
Commissioning
The gantry is commissioned using the WinPISA programming system. Proceed in the same way as when commissioning a single axis (see Exercise 2, Figure A2.1).

The following commissioning steps are performed in this exercise:
- Setting up the test environment
- Switching on the electrical power supply
- Switching the compressed air supply and conducting a function test (control direction, EMERGENCY-STOP)

Control direction
The two servo-pneumatic NC axes of the gantry operate on the basis of a closed position control loop. On both axes, the proportional valve and cylinder must be connected as follows (Figure A8.1):
- Port 2 of the proportional directional control valve connected to the cylinder chamber located on the side of the displacement measuring system plug.
- Port 4 of the proportional directional control valve connected to the chamber located on the side opposite to the displacement measuring system plug.

Only then will the slide move towards the setpoint position until this is reached (correct control direction), unless there is a system variation.

If the ports on the cylinder or on the valve are reversed, the slide will move away from the setpoint position under the influence of the controller (wrong control direction).



1 Electrical connection

Figure A8.1: Control direction: Required tubing connection of proportional directional control valve and cylinder:

The NC axes will not operate correctly if the control direction is wrong. The control direction must consequently be checked during commissioning and corrected if necessary.

Preconditions for checking the control direction

The following preconditions must be met:

- The system must be correctly set up and wired and the tubing must have been correctly connected.
- The test environment must have been installed (PC with WinPISA and interface cabling)
- The EMERGENCY-STOP button must have been unlocked
- The electrical power supply and the pneumatic supply must have been connected

Checking the control direction using WinPISA

Proceed as follows in order to check the control direction:

- Activate Online mode in WinPISA
- Choose command "Motion Test" in menu "Online", "Diagnosis" (Figure A2.5)
- Confirm the warning with "Continue"
- Choose the axis (x for horizontally arranged axis and y for vertically arranged axis)
- Vary the manipulated variable of the selected axis by clicking on the corresponding buttons.

If the piston of the axis in question moves and no message is displayed on the screen, the control direction is OK.

If you are prompted on screen to reverse the tubing connection, the control direction is the wrong way around. The following steps must be performed:

- Switch off the compressed air supply and ensure that no further pressure is applied.
- On the axis in question, swap the tubing either at the load ports of the proportional valve or at the cylinder
- Recheck the control direction for this axis

EMERGENCY-STOP: System behaviour
The EMERGENCY-STOP button must be pressed when the system has a malfunction or when a dangerous situation occurs.

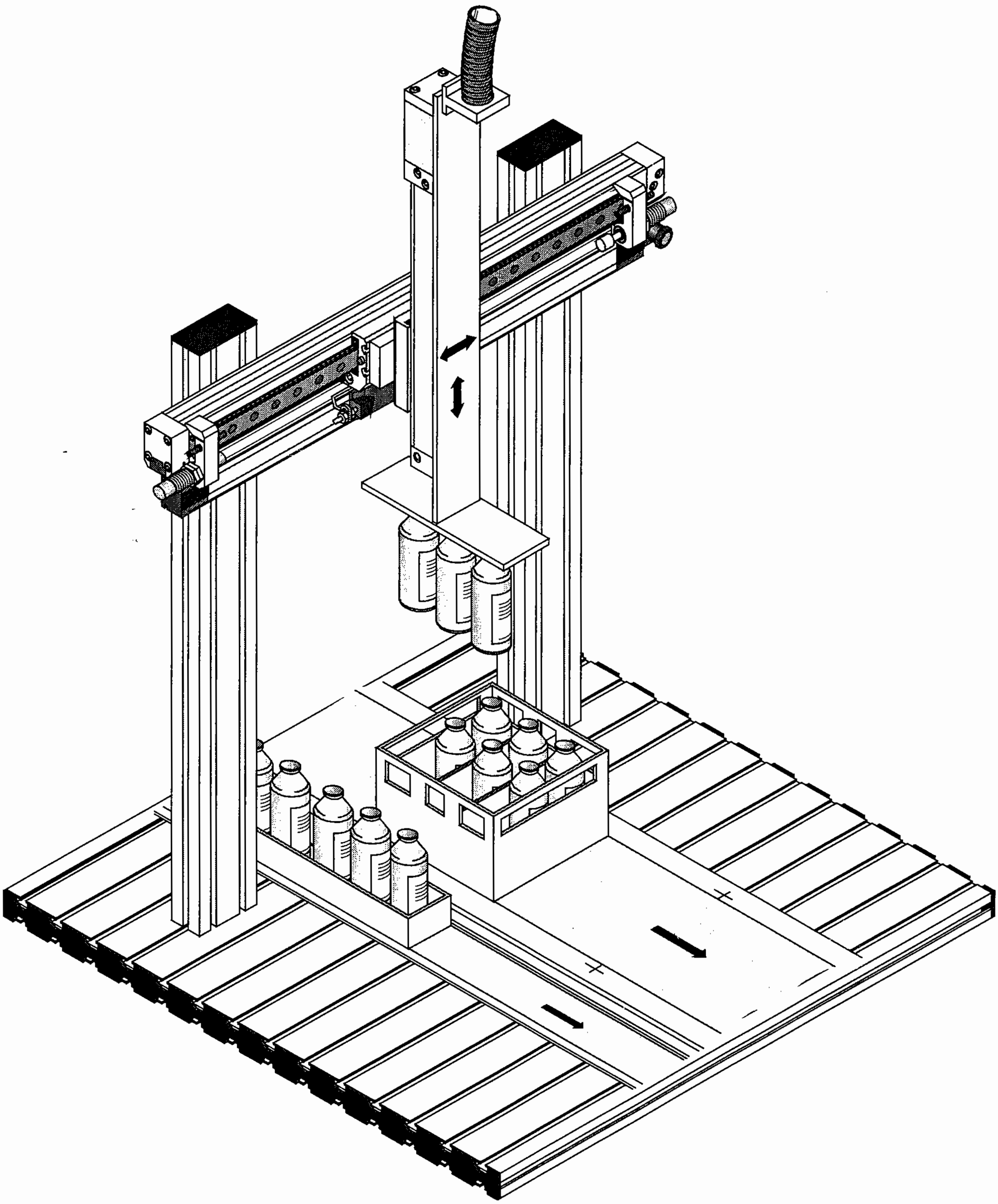


Figure A8.2: Application of a twin-axis gantry

Figure A8.2 shows an application for a twin-axis gantry. A favourable EMERGENCY-STOP behaviour is identified by:

- Deceleration of the horizontal axis (x) with as short a travel as possible
- Movement of the vertical axis (y) against the top stop

This reduces the risk that the vertical axis, the gripper or a workpiece collides with stationary parts.

EMERGENCY-STOP: Behaviour of the pneumatic circuit

The following measures are required in order to achieve the required behaviour:

- Clamping of the piston of the horizontal axis (x axis) by shut-off of the cylinder ports
- Pressurisation of the lower cylinder chamber of the vertical axis (y axis) and exhausting of the upper chamber.

Figure A8.3 shows the pneumatic circuit used to achieve this behaviour.

- In normal operation (EMERGENCY-STOP button unlocked) current flows through the solenoid of the 5/2-way valve. The 5/2-way valve and the four 3/2-way valves are actuated. The load ports 2 and 4 of the two proportional valves are connected to the related cylinder ports.
- In the case of EMERGENCY-STOP, the current through the solenoid of the 5/2-way valve is interrupted. The 5/2-way valve and the four 3/2-way valves switch to normal position. The connections between the proportional directional control valves and the cylinder chambers are disconnected. The piston of the x axis is clamped (control loop system 1 in the pneumatic circuit diagram). The piston for the y axis is moved against the upper stop (control loop system 2 in the pneumatic circuit diagram).

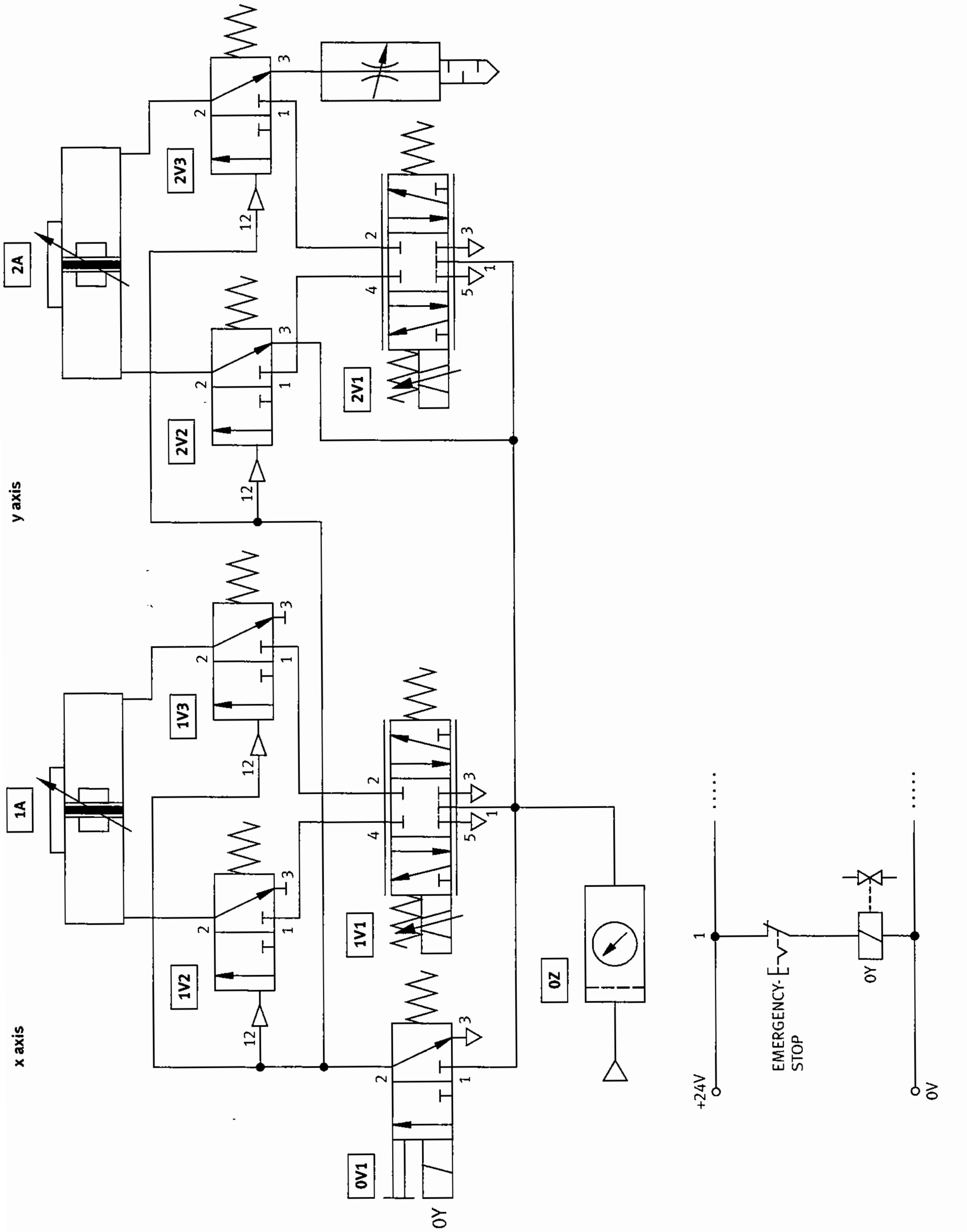


Figure A8.3: Pneumatic circuit diagram of the twin-axis gantry

EMERGENCY-STOP behaviour, vertical axis

The speed at which the vertical axis is moved upwards in the case of EMERGENCY-STOP can be set by exhaust air flow control. The following requirements must be met:

- Movement speed when EMERGENCY-STOP is pressed adequately high to retract the axis promptly from the collision area
- Movement speed not too high so that the axis is not decelerated too hard at the stop by the shock absorbers

The procedure for setting the movement speed is shown in Figure A8.4.

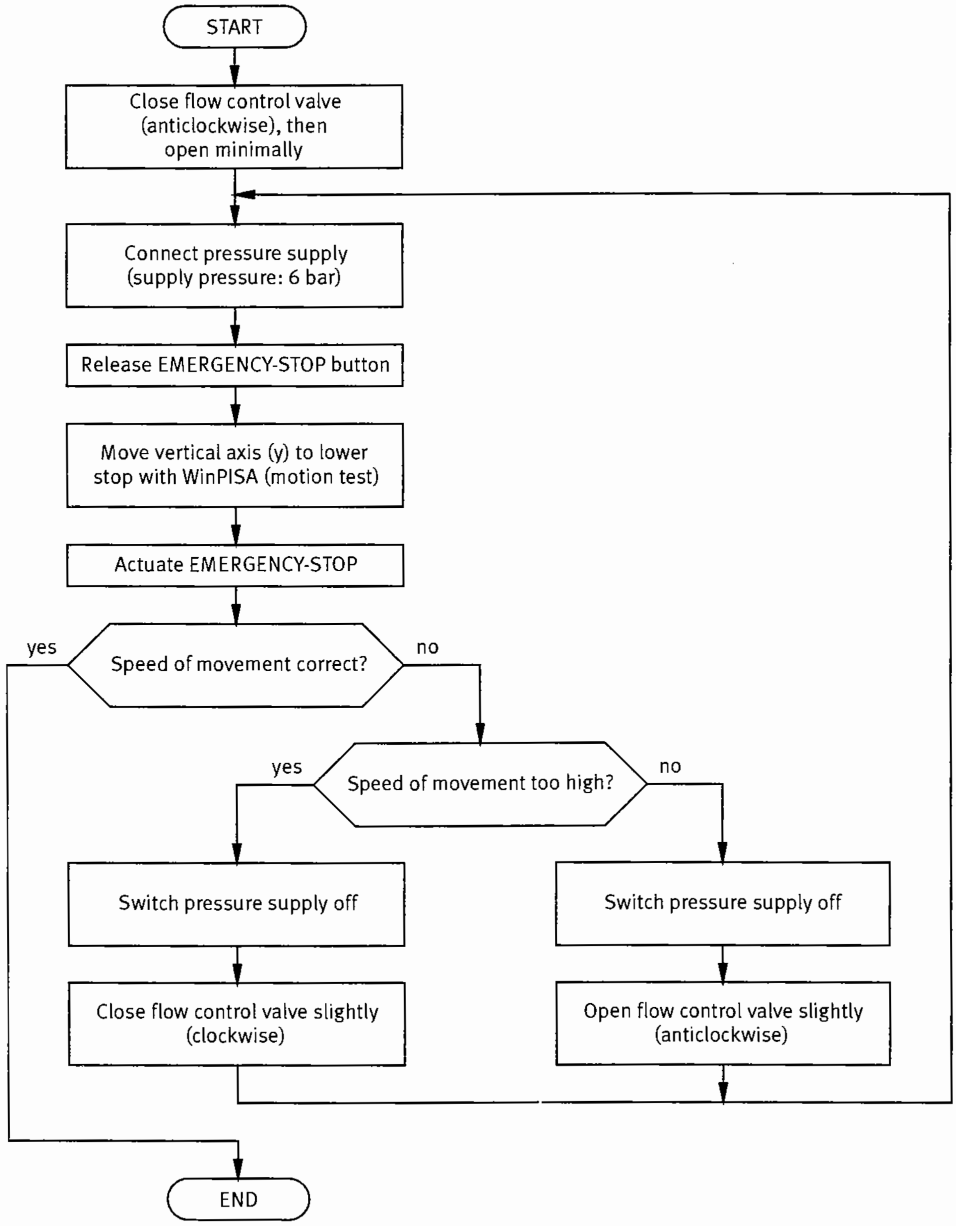


Figure A8.4: EMERGENCY-STOP behaviour: Setting the movement speed (y axis)

Problem description

A twin-axis gantry with two servo-pneumatic NC axes has been assembled, the tubing has been connected and it has been wired. The system is to be put into operation. For this purpose, the control direction must be checked on both axes. In addition, the EMERGENCY-STOP behaviour must be checked and optimised.

Positional sketch

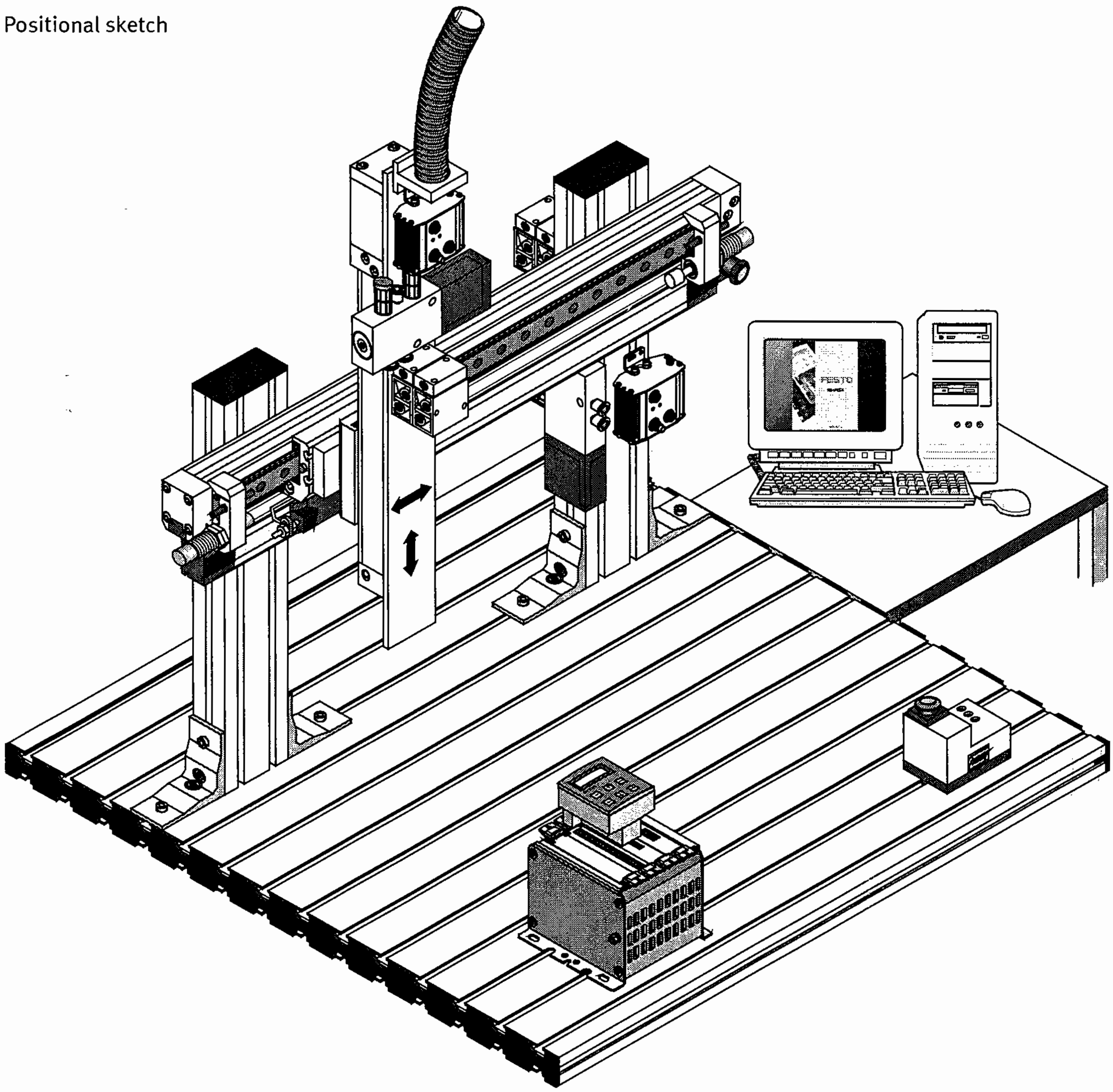


Figure A8.5: Positional sketch of the twin-axis gantry

Problem definition

- Putting the WinPISA-controller interface into operation
- Putting the linear axes into operation electrically and pneumatically
- Remedying any faults which occur
- Checking the control direction of both axes
- Checking and optimising the EMERGENCY-STOP behaviour of both axes

Procedure

1. Installing WinPISA
Check whether WinPISA is installed on your personal computer. If it is not, please proceed as follows, as described in Section "Technical knowledge" of Exercise 2.

2. Initialising the interface between personal computer and controller

- Check whether the connection between the interface of the controller and a serial port of the personal computer has been made.
- Launch WinPISA.
- If necessary, initialise the interface between PC and controller.

Further information on the interface between controller and personal computer can be found in Exercise 2 (Section "Technical knowledge; making connection between personal computer and controller") and in the WinPISA Manual .

Caution

Do not yet switch on the compressed air supply or the electrical power supply (24 V)!

3. Connecting the electrical power supply
Ensure that the EMERGENCY-STOP button is not pressed.

Switch on the 24 V supply voltage! Check

- whether the green LED on the controller is illuminated
- whether the control panel of the controller shows the following message:
  "SPC 200 Vnnnx
  Select with ()"
- whether the green LEDs on both axis interfaces are illuminated

Should this not be the case, first switch off the supply voltage and then check the cabling.

4. Activate "Online mode"

Activate Online mode in WinPISA (see Section "Technical knowledge").
If Online mode cannot be activated, check

- whether the power supply is switched on
- whether the interface cabling has been carried out with the correct cable
- whether the port configuration in WinPISA (Figure A2.4) corresponds to the port actually used in the PC

5. Connect the compressed air

Set a supply pressure of approx. 3 bar and connect the compressed air! The slides of both axes may not move even with the compressed air connected.

Caution

Danger: Keep well away from the traversing area of the slide!
Do not set a supply pressure higher than 3 bar so as to avoid damage to the axes during the test!

6. Check the control direction

Activate the motion test in WinPISA (see "Technical knowledge")

Conduct the motion test for the horizontal axis (x axis) first.
If the slide does not move, please check the following:

- Electrical supply and compressed air supply
- EMERGENCY-STOP button (if necessary: release the button; confirm the error message the next time the motion test is called)

If the slide moves but the control direction is incorrect:

- Switch off the compressed air
- Modify the tubing connection of the axis in question (see Figure A8.1 and Section "Technical knowledge, control direction")
- Connect the compressed air
- Recheck the control direction

As soon as the x axis operates correctly, check the control direction of the y axis in the same way.

7. Check the motion range
Activate the motion test in WinPISA (with EMERGENCY-STOP button unlocked).

Move both axes to the extreme positions (right and top, right and bottom, left and top, left and bottom). Check whether all positions are reached without the cable or tubing being kinked or becoming taut.

If necessary, modify the tubing connection and/or cabling resp. arrangement of the valves and interfaces appropriately. The system must then be retested.

8. Checking the EMERGENCY-STOP function
Set a supply pressure of approx. 3 bar.

Press the EMERGENCY-STOP button.
- The slide of the horizontal axis must stop.
- The slide of the vertical axis must move to the upper stop.

If this is not the case, check and correct the electrical and pneumatic circuit. Then unlock the EMERGENCY-STOP button and carry out a retest.
Press EMERGENCY-STOP again. Then activate the motion test in WinPISA. None of the two axes may respond to adjustment of the manipulated variable of the proportional valve.
If the required behaviour does not occur, check the wiring and tubing connection and correct them. Then conduct a retest.

If the tubing connection and/or the wiring have been modified for the check of the EMERGENCY-STOP behaviour, recheck the control direction. The following steps are required:
- Unlock the EMERGENCY-STOP button (pull it)
- Activate the motion test in WinPISA
- Recheck the control direction of the two axes
- Recheck the EMERGENCY-STOP behaviour

9. Setting of the EMERGENCY-STOP behaviour (y axis)
Set the movement speed of the y axis in the case of EMERGENCY-STOP (procedure: see flow chart, Figure A8.4).

Exercise 9
Configuring a machining station

Training aim

- To be able to set up a project for a twin-axis set-up using WinPISA
- To be able to configure a project for a twin-axis set-up

Technical knowledge

Project
A project is set up in WinPISA for each application. Creating a project covers the following steps:
- Set up the project
- Configure the project: Enter the information on the hardware used (controller and linear axes), identification of the system behaviour - programming: Defining the movement pattern, writing the motion program

A project for a twin-axis gantry is set up within the framework of this exercise. The project is also configured.

Configuring the controller hardware
Various controller configurations are used depending on application (one axis, two axes or additional functions). The program written using WinPISA must match the controller configuration used. The simplest way of doing this is to load the controller configuration directly from the controller to WinPISA.

The following entries are required:
- Activate Online mode
- Click on the Hardware icon with the right mouse button and then click on "Insert Object" and "Controller SPC 200"
- Click on "Upload" (Figure A9.1)
- Confirm with "Ok"

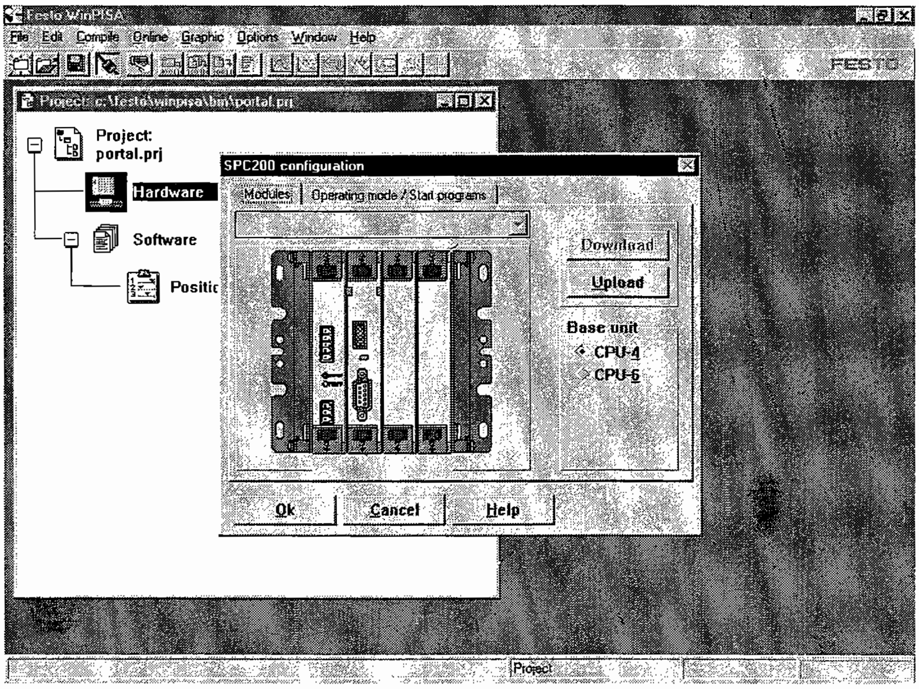


Figure A9.1:Configuring the controller

Entry: axes used
The gantry features two linear axes. The pneumatic components and the displacement measuring systems of these two axes are listed in Table A9.1.

Axes		**x**	**y**
Cylinder	Type Piston diameter Piston stroke	DGP rodless 25 mm 450 mm	DGP rodless 25 mm 225 mm
Displacement measuring system	Type Measuring length	Potentiometer 450 mm	Ultrasonic (Temposonic) 225 mm
Proportional directional control valve	Type Flow factor of the proportional directional control valve	MPYE 5-1/8-LF 1	MPYE 5-1/8-LF 1

Table A9.1: Pneumatic components and displacement measuring systems of the two NC axes

The following entries must be made in order to configure the x axis:

- Click on "SPC200" with the right mouse button and then click on "Insert Object" and "Positioning Axis"
- Select the correct cylinder type (see Table 9.1)
- Confirm your choice with "Ok"

Then configure the y axis in the same way. Figure A9.3 shows a project after both linear axes have been configured..

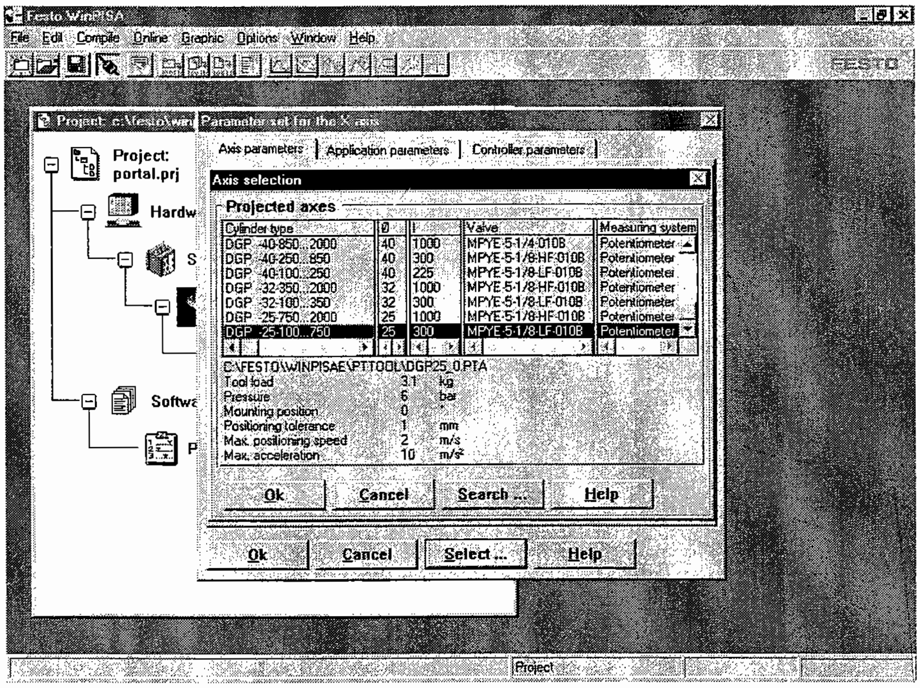


Figure A9.2: Configuring a linear axis (positioning axis)

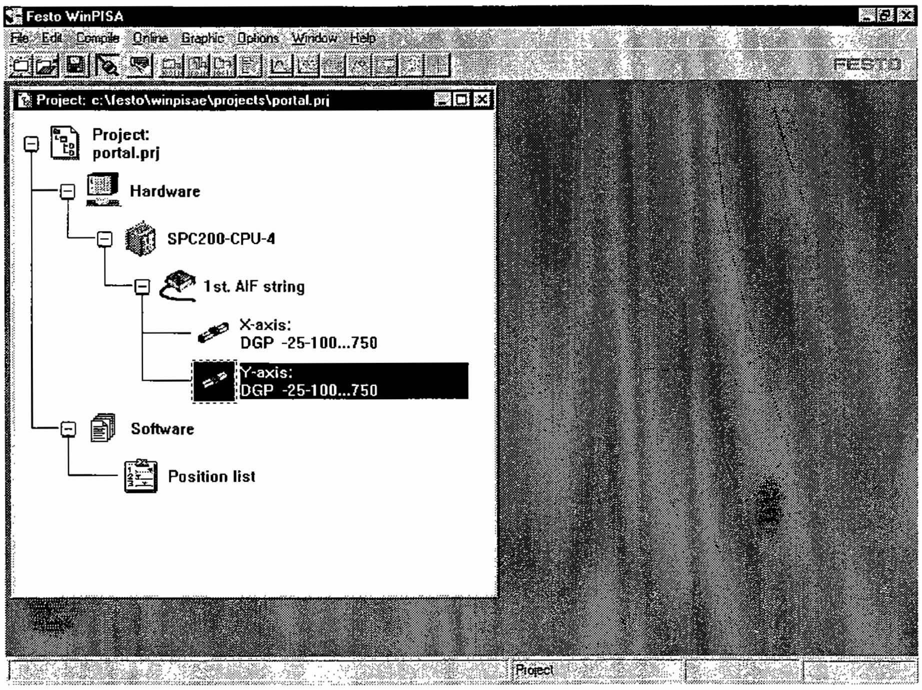


Figure A9.3: Project (configured for twin-axis gantry)

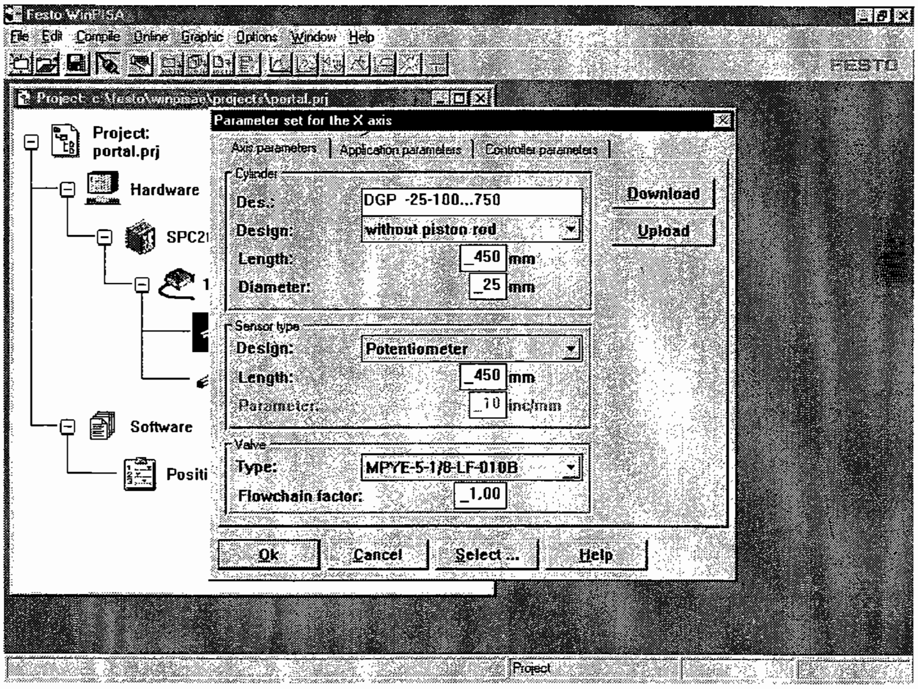
Entering and changing the axis data

The features of the axes used are described by the axis, application and controller data.

The following steps are required in order to enter or change the axis data:

- Click on the required axis (x or y) and "Configure" with the right mouse button in the Project window
- Click on the "Axis Data" field
- Enter the cylinder length, potentiometer length and flow factor of the valve (Table A9.1)
- Confirm your entry with "Ok"

The axis data must be entered for the x axis and for the y axis.



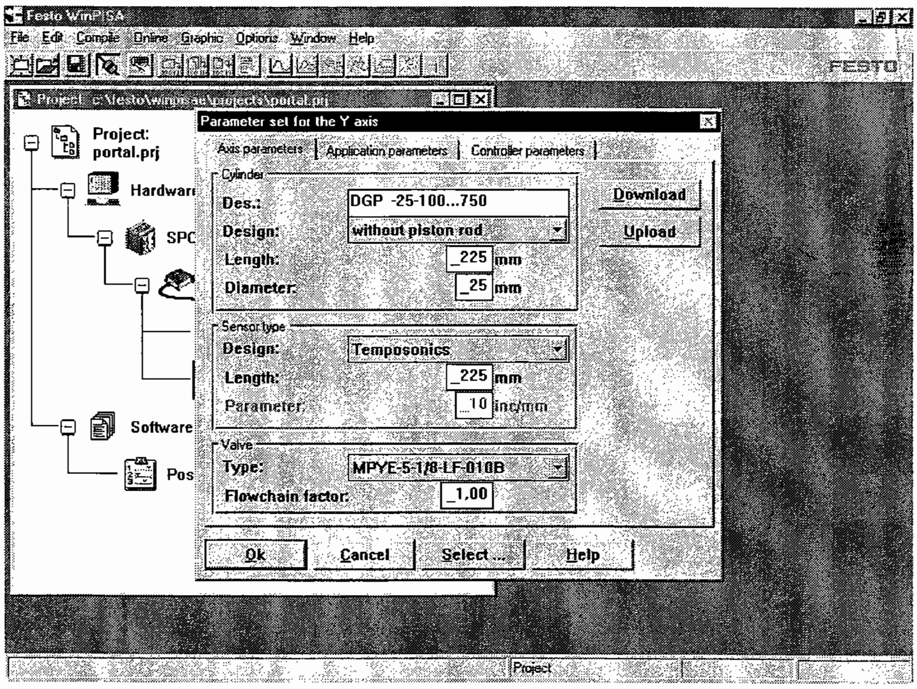


Figure A9.4: Axis data (x axis and y axis)

Entering and changing the application data

You must click on the required axis, "Configure" and button "Application Data" in the Project window in order to display or modify the application data.

The application data specified in Figures A9.5 and A9.6 achieves correct functioning of the servo-pneumatic NC axis. Please refer to the WinPISA Manual, Chapter. 4.4.2, for a precise explanation of the significance of the application data.

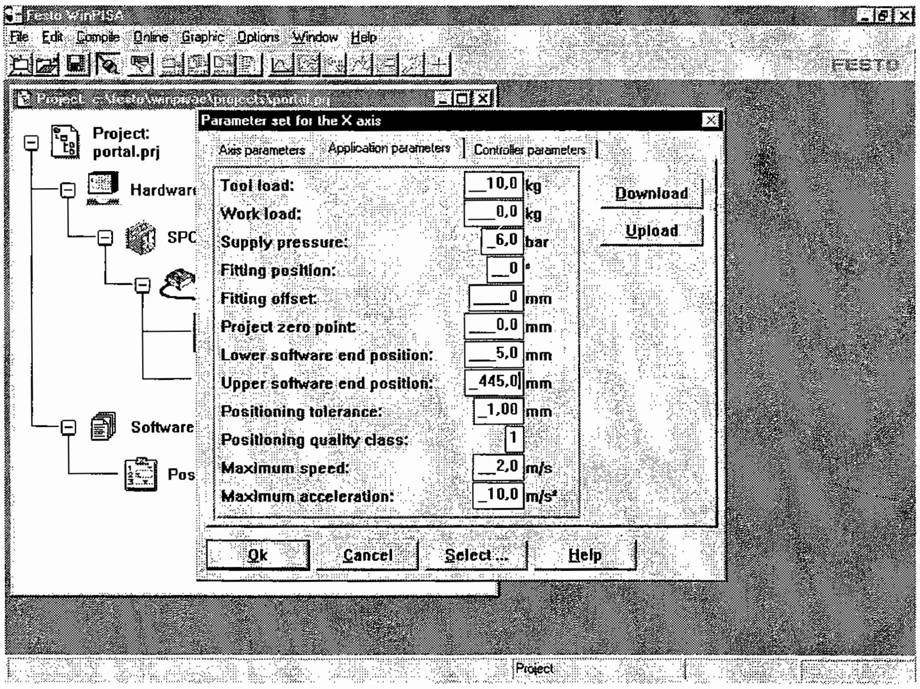


Figure A9.5: Application data (x axis)

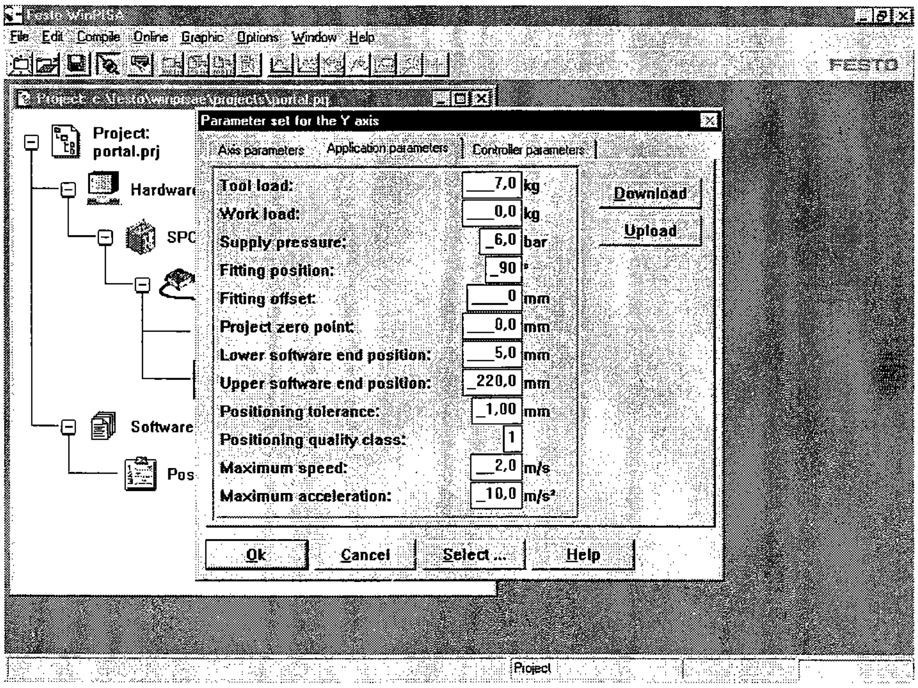


Figure A9.6: Application data (y axis)

Defining the controller data

The controller data is displayed if you click on the "Controller Data" button in the Positioning Axis window. The default data normally ensures a good movement behaviour (Figure A9.7). Consequently, this data should not be changed.

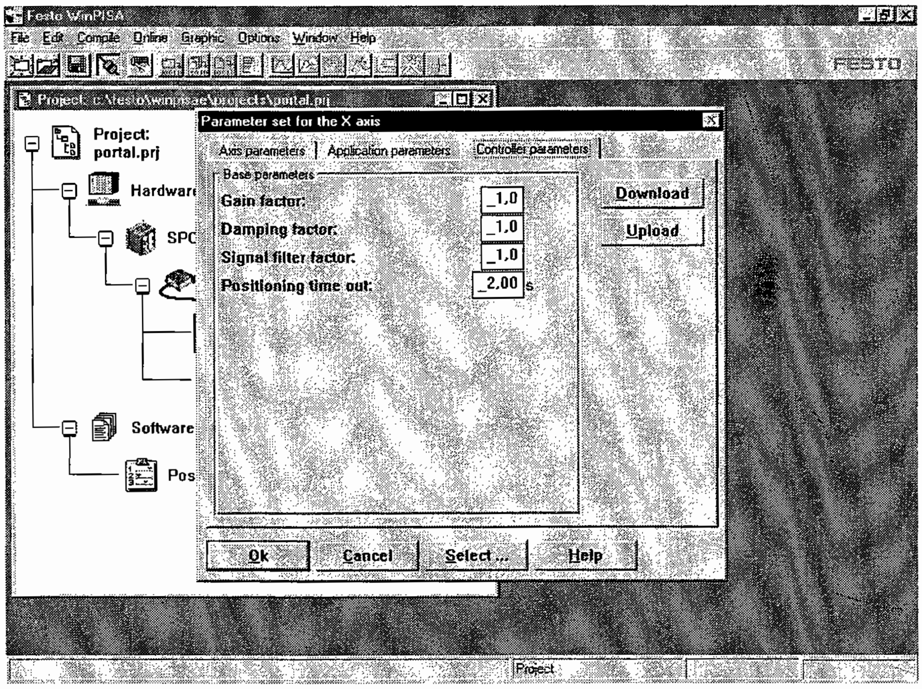


Figure A9.7: Controller data

Identification

The movement behaviour of a servo-pneumatic linear axis is influenced by numerous factors. Certain factors are subject to production tolerances or are not adequately known to the user. Examples of these are:

- The manipulated variable at which the valve is closed
- The frictional force of piston seal and linear guide
- The exact, moving mass
- Supply pressure fluctuations
- The tubing volumes between proportional directional control valve and cylinder

Consequently, in addition to entering the axis data, application data and controller data, it is also necessary to perform an identification determined by the actual movement behaviour of the axis. It covers the following functions:

- The manipulated variable for the valve is varied on the basis of a defined procedure.
- The movement behaviour of the slide is measured.
- Characteristics that influence the controller setting are computed from the measured result.

Identification: Procedure

For the problem in question, it is practical to conduct a static identification and a dynamic identification with both axes. During the identification process, the selected NC axis performs numerous movements that also need to be evaluated. Dynamic identification in particular thus takes longer.

The identification must be started as follows:

- Ensure that Online mode is active
- Choose command "Identification" in menu "Online", "Commissioning"
- Confirm the message with "Continue"
- Choose the axis (with "Axis X" resp. "Axis Y" and identification ("Static Identification" resp. "Dynamic Identification without Useful Load") (Figure A9.8)
- Click on "Start"

Caution

- The supply pressure during identification must correspond to the supply pressure during the subsequent application (generally 6 bar)!
- Risk of injury: The selected axis moves with high force and at high speed during the identification!

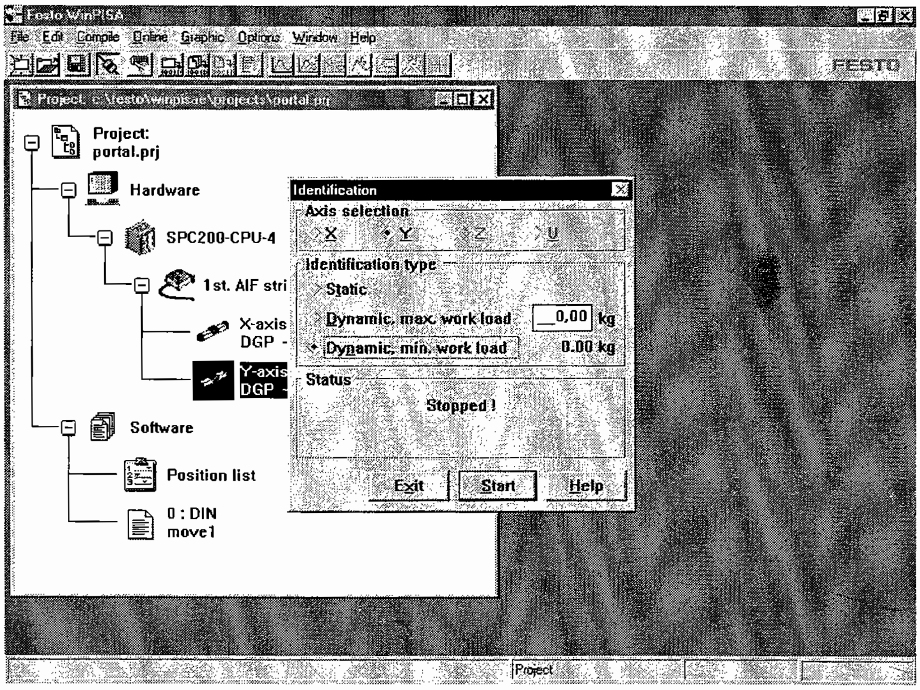


Figure A9.8: Dynamic identification (y axis)

Problem description

A machining station with two pneumatic NC axes has been set up. The hardware has been tested and put into operation. In the next step, a project is to be configured and programmed in WinPISA. In addition, a static identification and a dynamic identification must be conducted for both linear axes.

Positional sketch

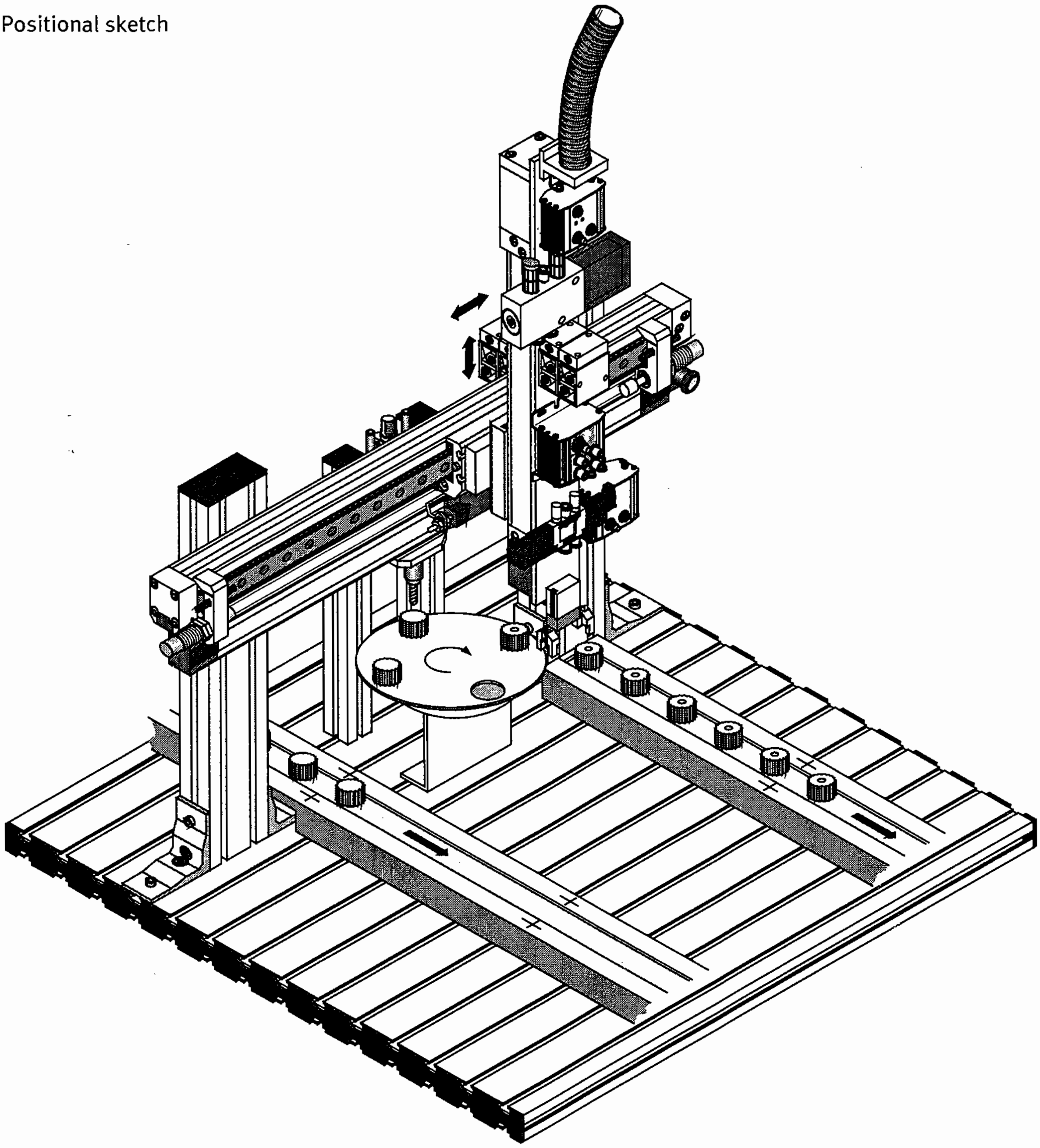


Figure A9.9: Positional sketch of the machining station

Problem definition

- Create the project
- Configure the project for the twin-axis gantry
- Conduct identification on the twin-axis system

Procedure

1. Create the project
Create a project named "Machining"!

2. Configure the hardware
Switch on the controller's power supply. The compressed air supply must remain switched off for the time being.

Configure the following for this project.

- Controller
- Axis data (x axis)
- Application data (x axis)
- Controller data (x axis)
- Axis data (y axis)
- Application data (y axis)
- Controller data (y axis)

3. Conduct identification

- Switch on the compressed air supply.
- Set a supply pressure of 6 bar.
- Conduct the identification in the following order:
  - Static identification (x axis)
  - Dynamic identification (x axis)
  - Static identification (y axis)
  - Dynamic identification (y axis)

Exercise 10
Unloading a pallet

Training aim

- To be able to program a motion sequence for the twin-axis gantry
- Being able to use various traversing commands
- Familiarising yourself with symbolic programming

Technical knowledge

Procedure for programming

The procedure for programming the twin-axis gantry is shown in the flow chart, Figure A10.1. It corresponds to the procedure when programming an axis.

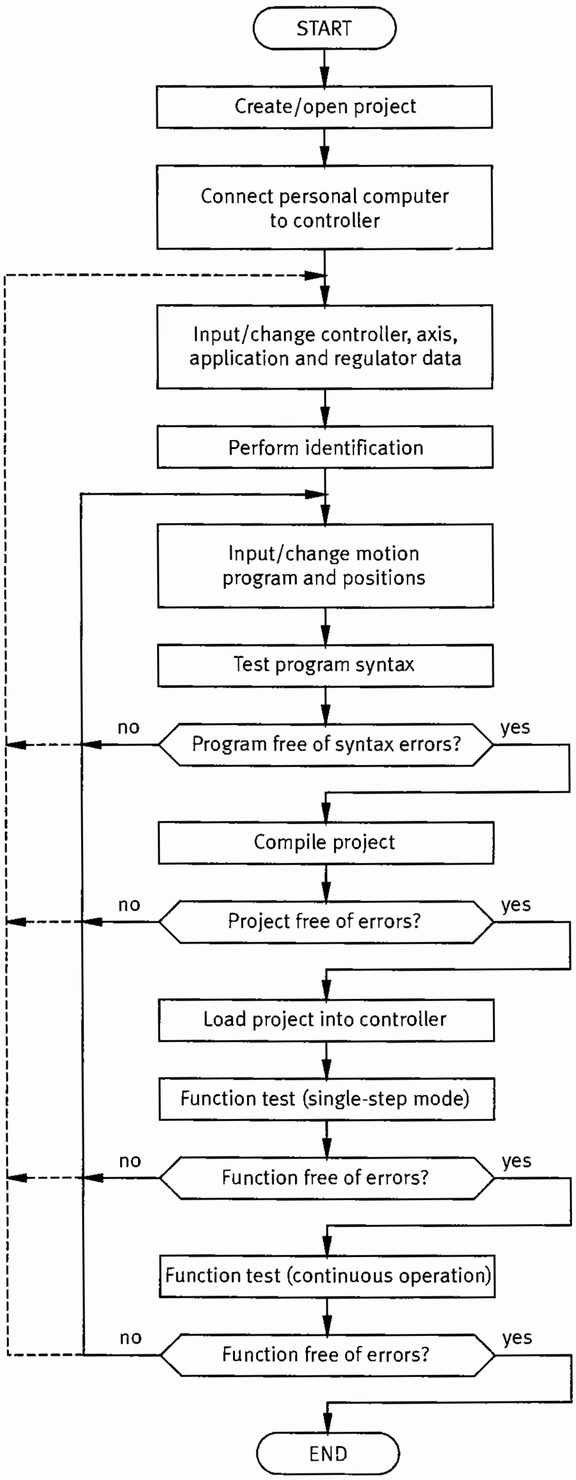


Figure A10.1: Procedure when programming using WinPISA

Traversing commands for two axes

The twin-axis gantry has the following options for moving the axes NC-controlled (Figure A10.2):

- only the x axis
- only the y axis
- both axes simultaneously.

In the latter case, the traversing operation is only complete when both axes have reached the new position.

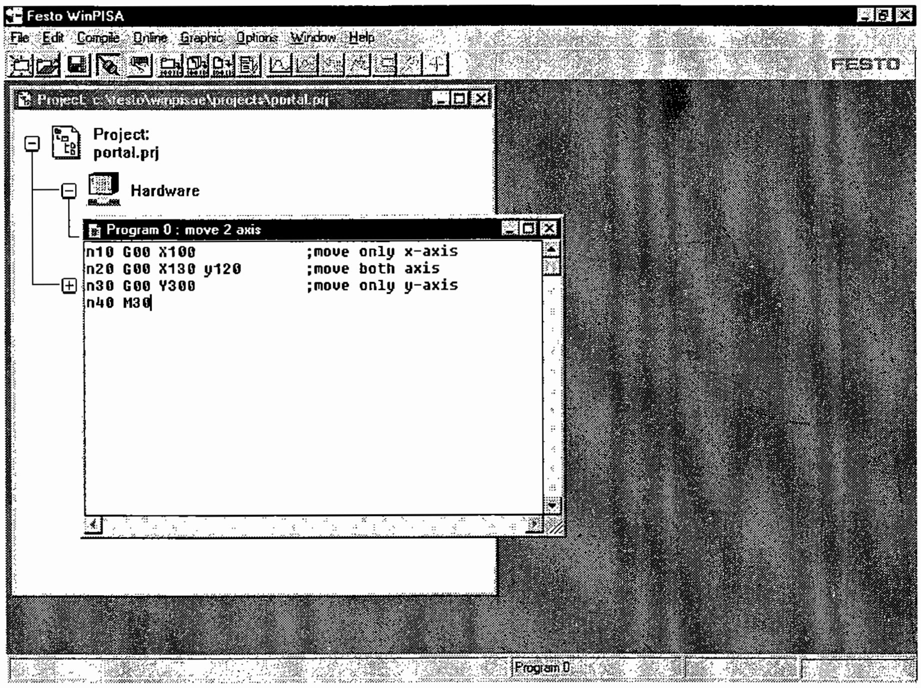


Figure A10.2: Traversing commands for two axes: Examples

Traverse command G00

Command G00 serves to traverse the axes as quickly as possible but free of overshoot. The maximum values of speed, acceleration and deceleration determined during the identification are utilised for this purpose. Figure A10.4 shows the related characteristics of the desired position s, desired speed v and desired acceleration a.

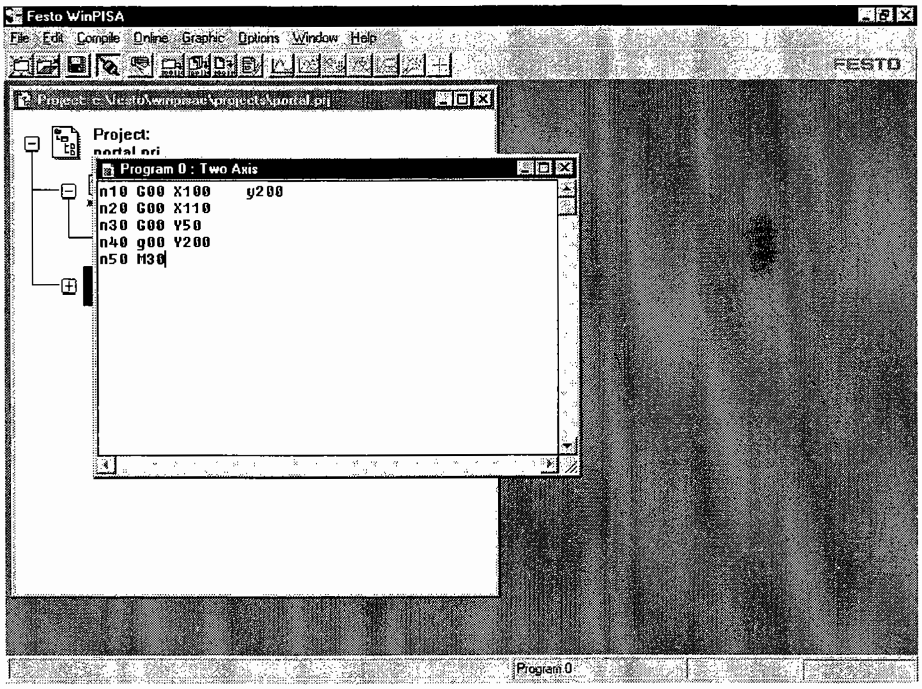
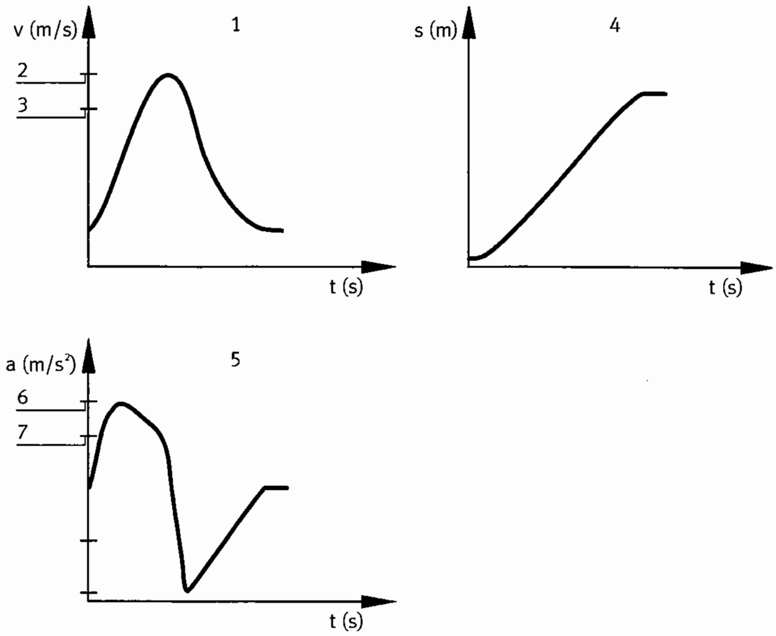


Figure A10.3: Traverse command G00: Example program

Caution

Command G00 may be used only if the dynamic identification has been performed beforehand.

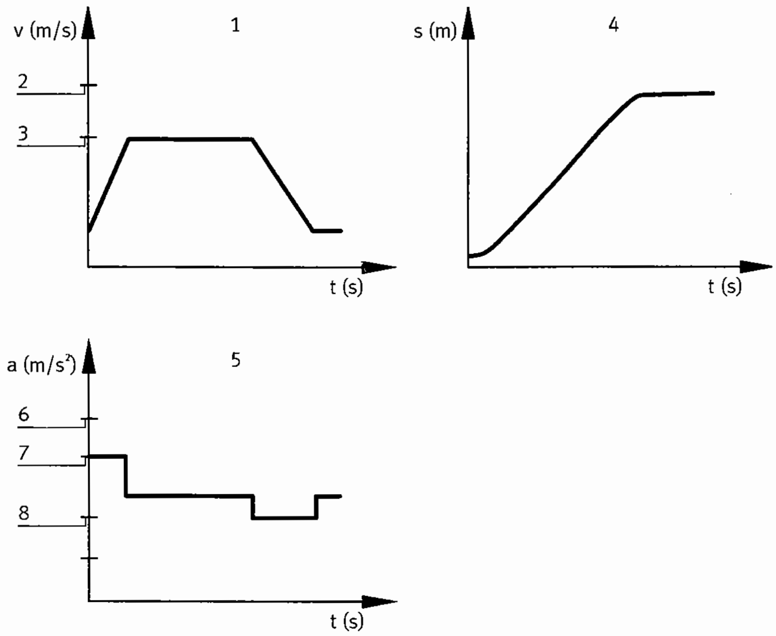


1	Speed setpoint value
2	Identified maximum speed
3	Configured maximum speed (G01/G02)
4	Position setpoint value
5	Acceleration setpoint value
6	Identified maximum acceleration
7	Configured maximum acceleration (G01/G02)

Figure A 10.4: Traverse command G00: Movement pattern

Traverse command G01

In case of command G01, the axes are traversed at defined speed, acceleration and deceleration (Figure A10.5).



1	Speed setpoint value
2	Configured maximum speed
3	Programmed speed
4	Position setpoint value
5	Acceleration setpoint value
6	Configured maximum acceleration
7	Programmed acceleration for acceleration ramp (G08)
8	Programmed acceleration for deceleration ramp (G09)

Figure A10.5: Traverse command G01: Movement pattern

The maximum speed is preset via FX resp. FY.

- In the case of FX00 resp. FY00, the maximum speeds corresponds to the values of the axis parameters.
- With FX01 to FX99 resp. FY01 to FY99, the speed is reduced to a value between 1 and 99% of the presetting.

Without additional information, the values preset with the axis parameters apply to acceleration and deceleration.

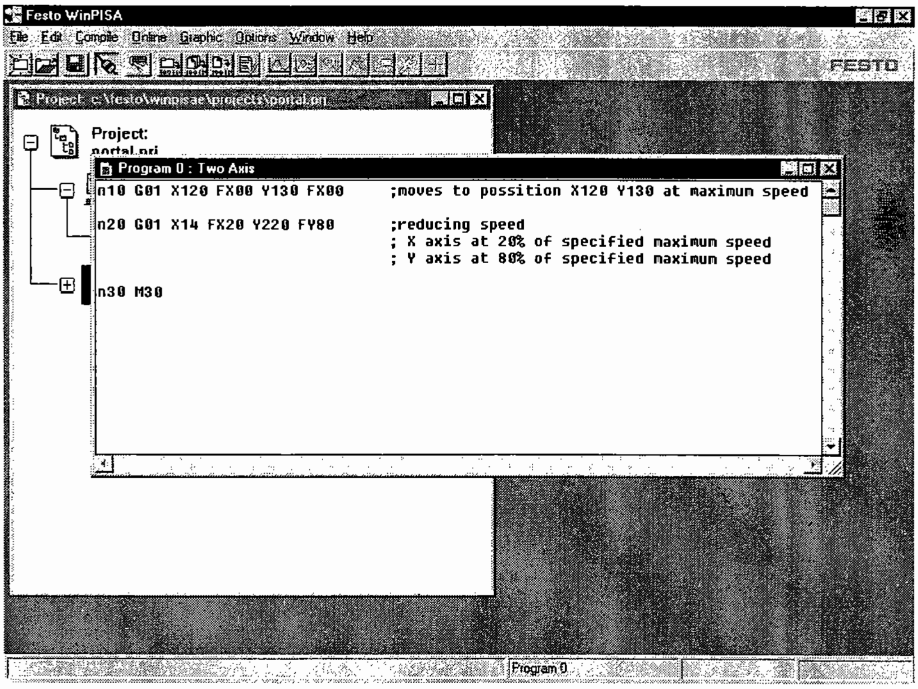


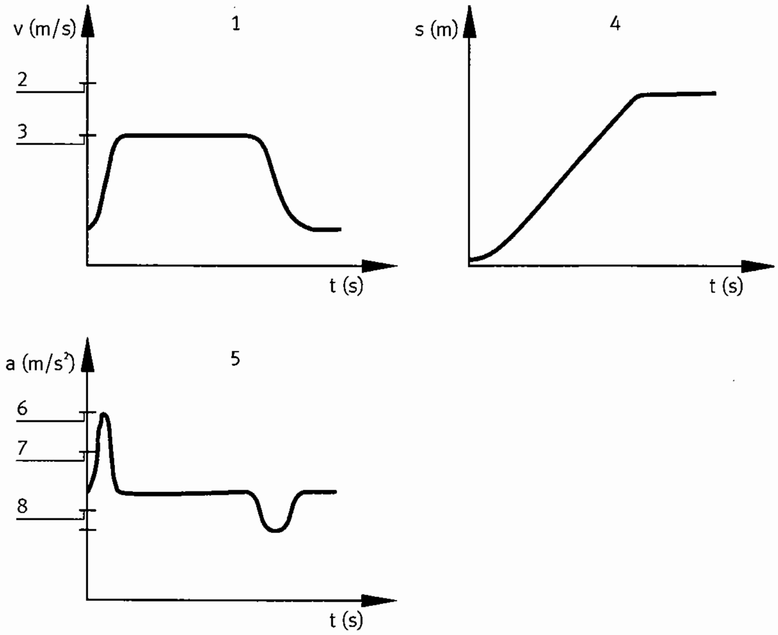
Figure A10.6: Traverse command G01: Example program

Traverse command G02

Commands G02 and G01 have the following in common:

- The axes traverse at defined speed, acceleration and deceleration.
- The default value of the maximum speed (FX resp. FY) is identical.

In the case of command G02, the same acceleration resp. deceleration, on average, is active as with G01. Owing to the softer acceleration and deceleration preset, the maximum values are higher so as to be able to position as quickly (Figure A10.7).



1 Speed setpoint value
2 Configured maximum speed
3 Programmed speed
4 Position setpoint value
5 Acceleration setpoint value
6 Configured maximum acceleration
7 Programmed acceleration for acceleration ramp (G08)
8 Programmed acceleration for deceleration ramp (G09)

Figure A10.7: Traverse command G02: Movement pattern

Commands G08 and G09

The acceleration is reduced during start-up with command G08, the acceleration when stopping is reduced with G09. Both commands have the following features:

- They act in conjunction with commands G01 and G02.
- They act latching , i.e. until the same command is issued with a different value.

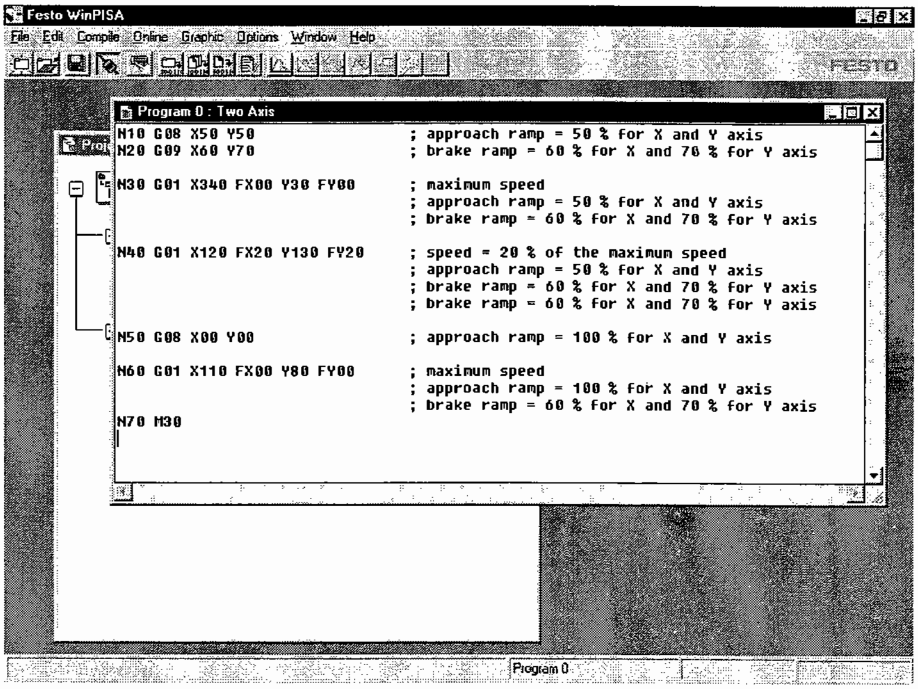


Figure A10.8: Commands G01, G08, G09: Example program

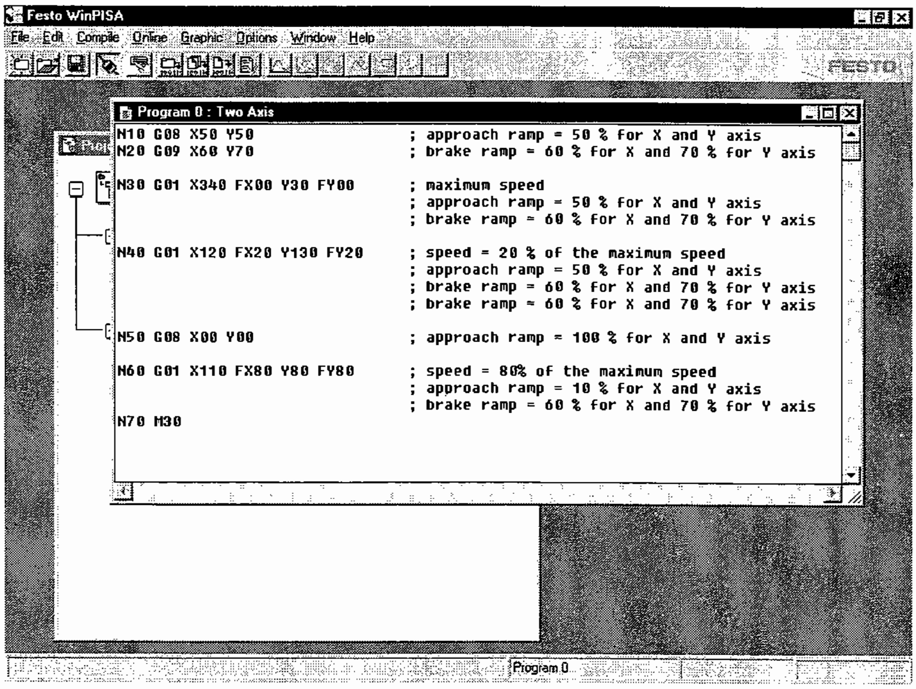


Figure A10.9: Commands G02, G08, G09: Example program

Symbolic programming: Position list

Names can be issued for the positions approached by the gantry. They are saved in the position list. The following entries are required (Figure A10.10):

- Select the position list in the Project window
- Enter the names
- Enter the x and y values

Comments may be entered in the fields scheduled in order to enhance readability.

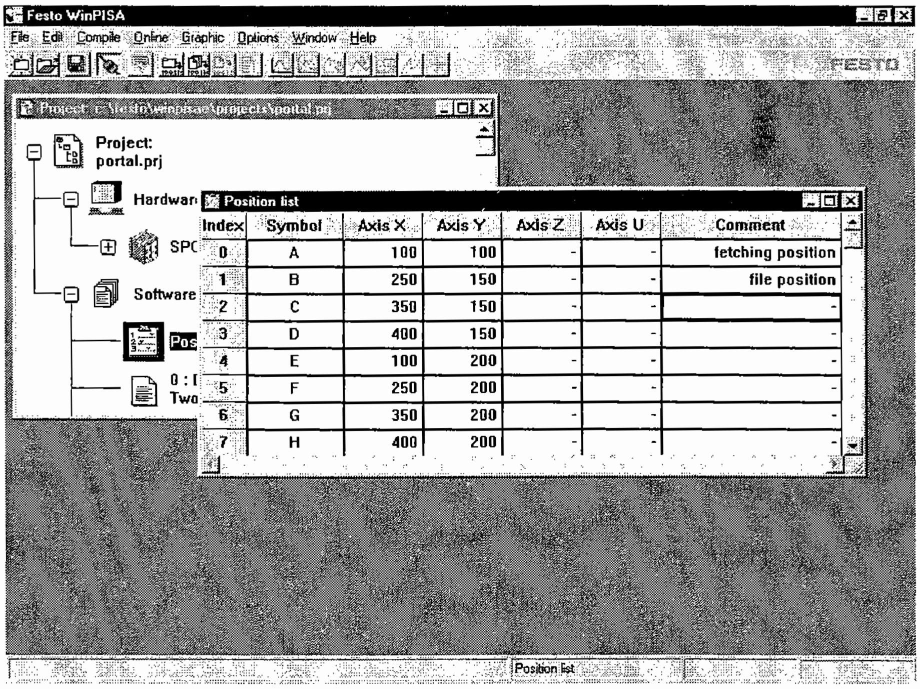


Figure A10.10: Position list

Symbolic programming: Traverse commands

In the case of the traverse commands, character @ and the name of the required position from the position list are used instead of the coordinates for the x and y axis (Figure A10.11).

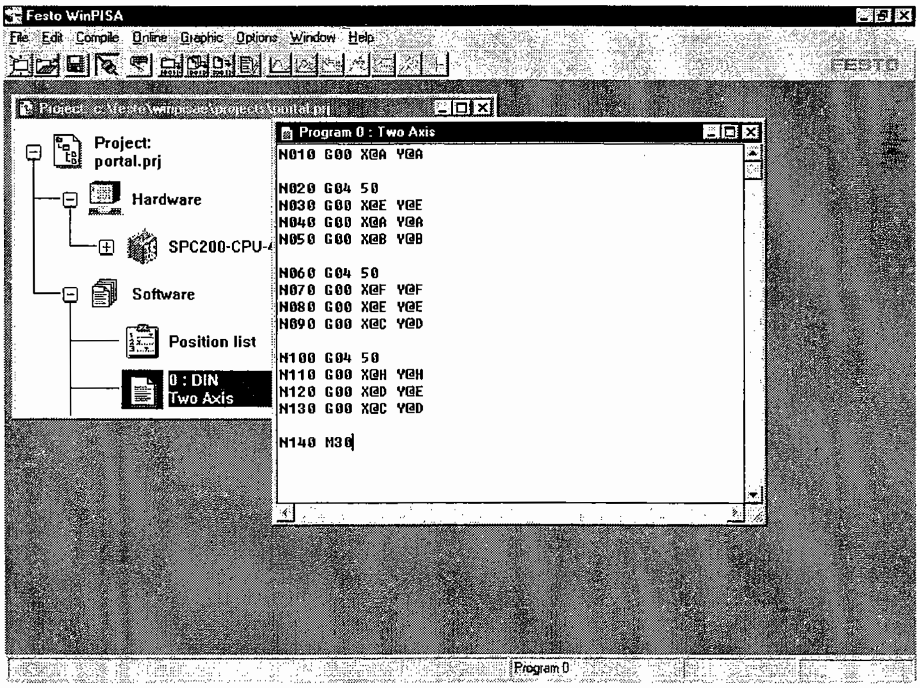


Figure A10.11: Traversing commands for symbolic programming

Symbolic programming: Teach-in of positions
In the case of applications of pneumatic NC axes (e.g. Figure A10.13), the x and y values of the positions to be approached are frequently not precisely known. This means that they cannot be entered directly on the keyboard. Instead, each position is approached via the gantry. The position of the axes is then transferred to the position list.

This requires the following steps in detail:
- Activate "Online mode"
- Click on "Edit" and "Optimise Positions"
- Acknowledge the error message with "Continue"
- Choose the required position in the "Optimise Positions" window (Figure A10.12)
- Traverse both axes to the required position (actual position is displayed)
- Transfer the position value to the list by "Enter"
- Perform steps Select Position, Traverse Axis and Enter Position in List for all required positions
- Click on "Quit".

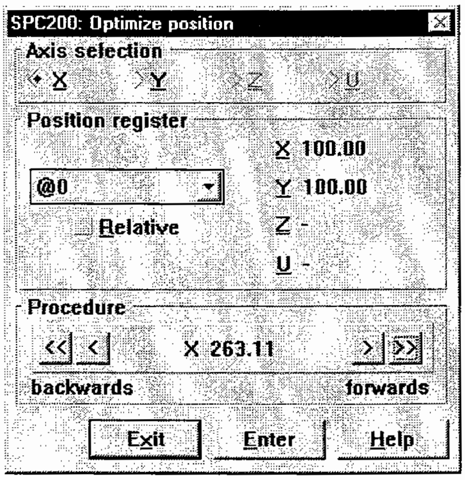


Figure A10.12: Teaching in positions

Problem description

Ready-machined gear wheels are fed on a pallet. There are three gear wheels next to each other on each pallet. A gantry with two NC axes picks-up the gear wheels and deposits them on the conveyor belt with which they are transported to transmission assembly.

A program must be written for this operation.

Positional sketch

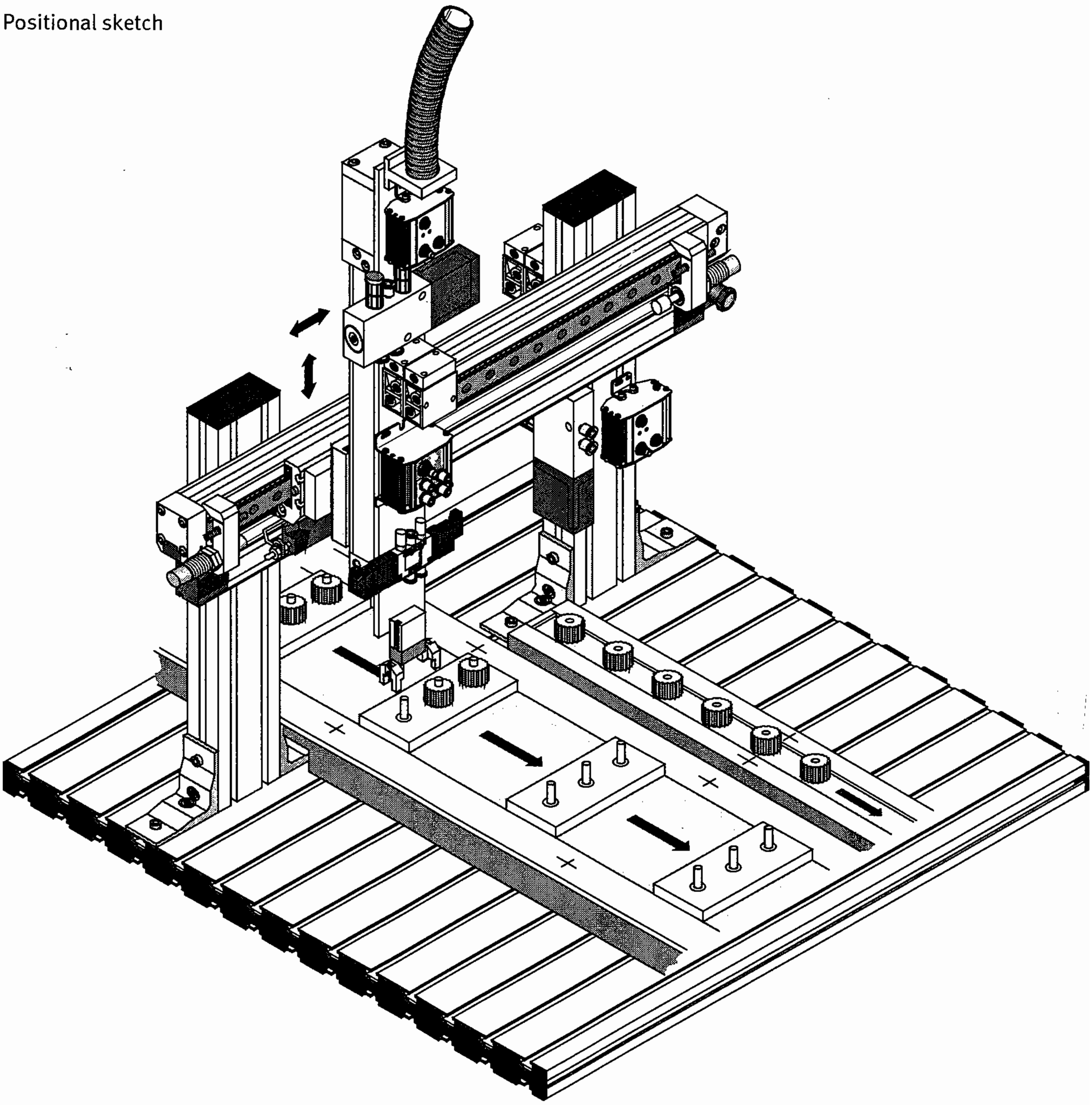


Figure A10.13: Positional sketch of the pick-up device

Problem definition

- Creating and configuring the project
- Creating a position list
- Writing the motion program
- Testing the motion program
- Optimising the traversing speed

Procedure

1. Creating the project and configuring the hardware
Create a project named "Pick"! Configure controller, axis data and application data for this project.

2. Positional sketch
Draw a positional sketch.
Enter all required positions on the positional sketch with names.

3. Position list
Write the position list.
Teach in the required positions via the gantry.

Caution

The axes perform movements with high force when teaching in the positions. Keep well away from the motion range of the axes!

4. Designing, entering and compiling the program
The following boundary conditions apply:

- In order to avoid damage to workpieces, these must be raised vertically upwards and deposited vertically downwards.
- The system must wait 0.5 seconds at each pick-up position and at the deposit position

Write the NC program for the pick-up device. Conduct the syntax text, error correction and compilation procedure.

5. Program test
Test your program in single-step mode.

If the axes do not move as required, please proceed as described in Exercise 3 in Section "Technical knowledge" under "Fault-clearance".

Start continuous operation and observe the movements of the slide.

6. Different traverse commands
Modify your programs so that only traverse command G00 is used. How do the axes move?

Modify your program so that only traverse command G01 is used. How do the axes move?

Modify your program so that only traverse command G02 is used. How do the axes move?

In conjunction with command G01, reduce the following for all downward movements of the y axis:
- the speed to 20 %
- the start-up acceleration to 50 %
- the braking acceleration to 10 %

Observe the behaviour of the system!

Exercise 11
Assembling and commissionning a gripper

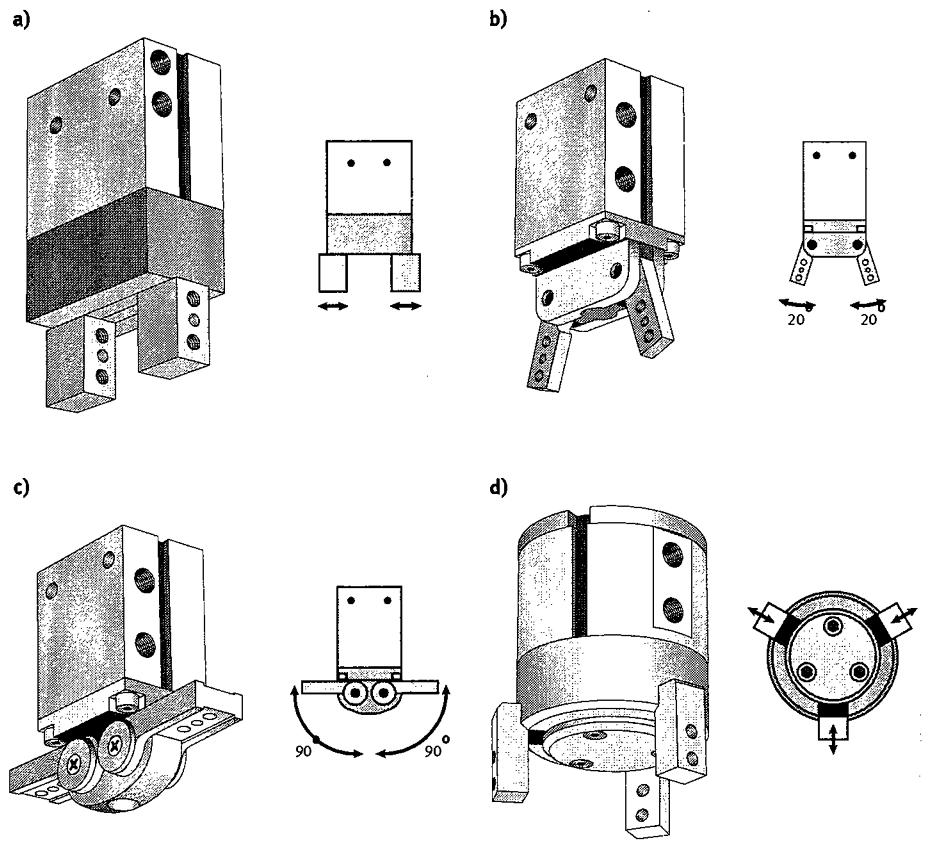
Training aim

- To be able to mount grippers
- To be able to connect the tubing and wiring
- To be able to put grippers into operation

Technical knowledge

Designs of pneumatic grippers

Pneumatically driven grippers are used to handle workpieces. Figure A11.1 shows various gripper types. Selection of the particular gripper will depend on the form of the workpieces to be handled. In the case in question, a parallel gripper is used.



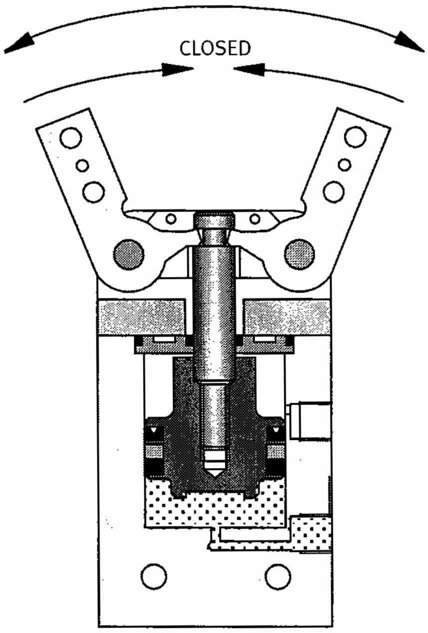
a) Parallel gripper
b) Angle gripper
c) Radial gripper
d) 3-point gripper

Figure A11.1: Designs of pneumatic grippers

Structure of a pneumatic gripper

Figure A11.2 clearly shows the structure of a pneumatic gripper. A double-acting pneumatic cylinder serves as the drive. Proximity switches can be attached for monitoring the gripper function.

a)



b)

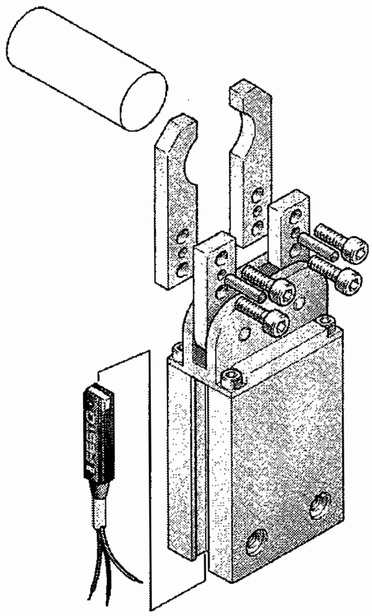


Figure A11.2: Structure of a pneumatic gripper

Gripper: Pneumatic circuit diagram

In the event of failure of the electrical power, the gripper must neither drop the workpiece nor grip the workpiece suddenly. In order to achieve this, it is actuated by a 5/2-way double solenoid valve that retains its switched position in the event of power failure (Figure 11.3).

Circuit diagram, pneumatic

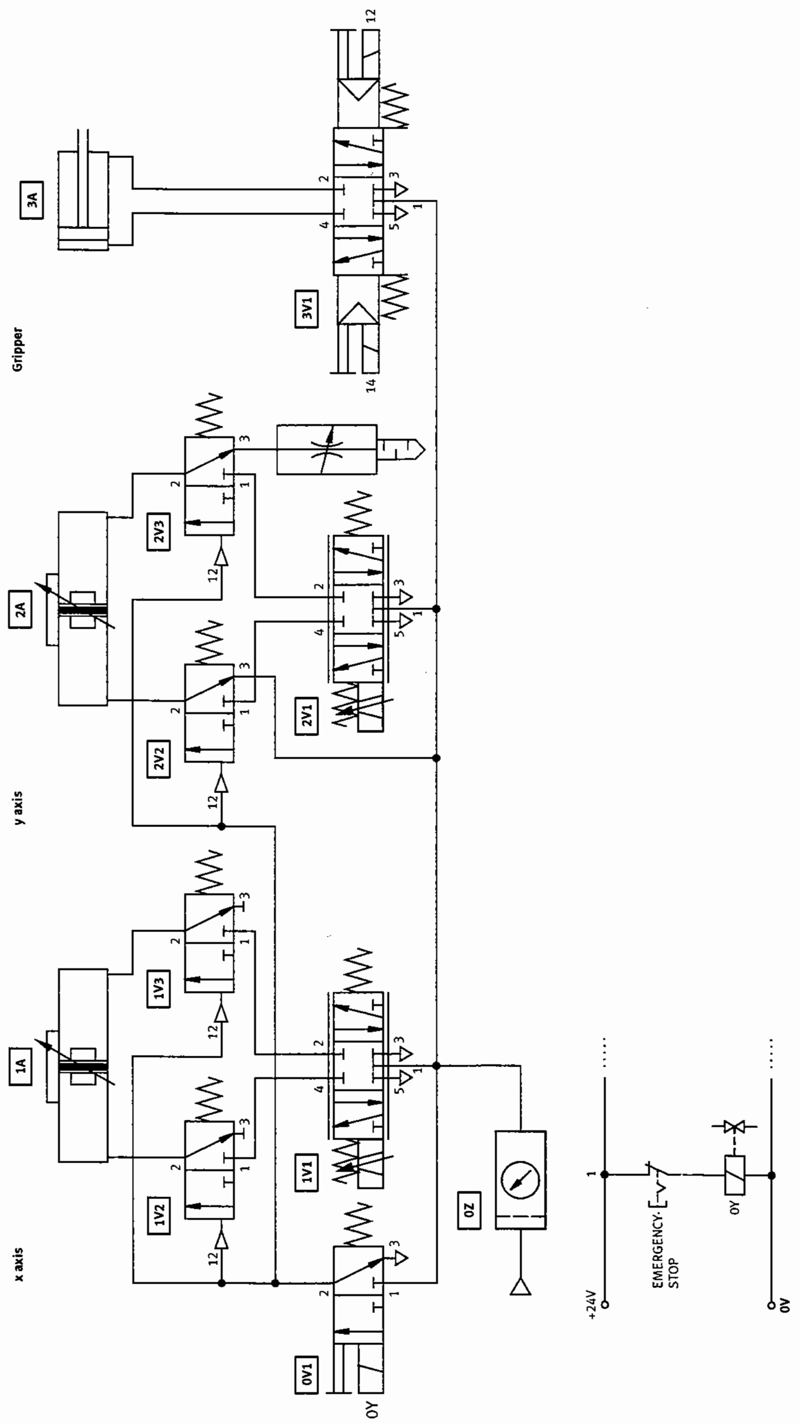
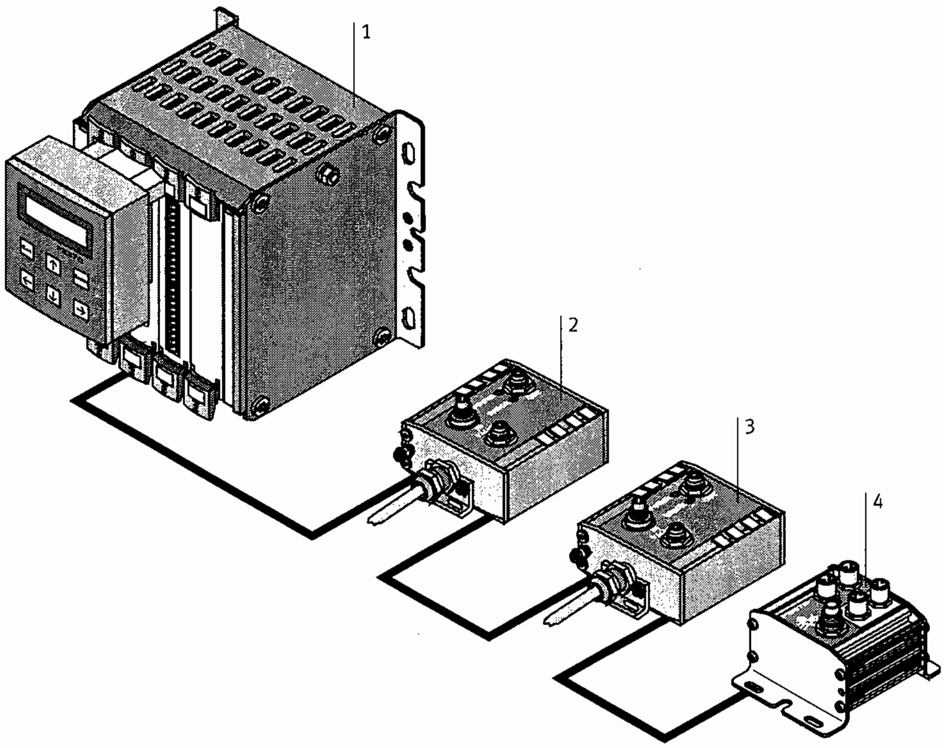


Figure A11.3: Pneumatic circuit diagram of the gantry with gripper

Open-loop and closed-loop control
Controller SPC 200 performs open-loop and closed-loop control of the pneumatic NC axes and open-loop control of the gripper.

The following components are required for the twin-axis gantry with gripper:
- Controller SPC 200
- Control panel
- Axis interface for horizontal axis (with dark cable and black plug)
- Axis interface for vertical axis (with bright cable)
- Module with binary inputs and outputs

Modules of the controller



1	Possible alternatives
2	Axis interface of the x axis
3	Axis interface of the y axis
4	Module with inputs and outputs

Figure A11.4: Controller modules for a twin-axis application with gripper

Assembling the gripper components

The components required for the gripper must be assembled on the mounting plate of the y axis (1) (Figure A11.5). These are as follows:

- the gripper (4)
- the 5/2-way double solenoid valve (3)
- the module with binary inputs and outputs (2)

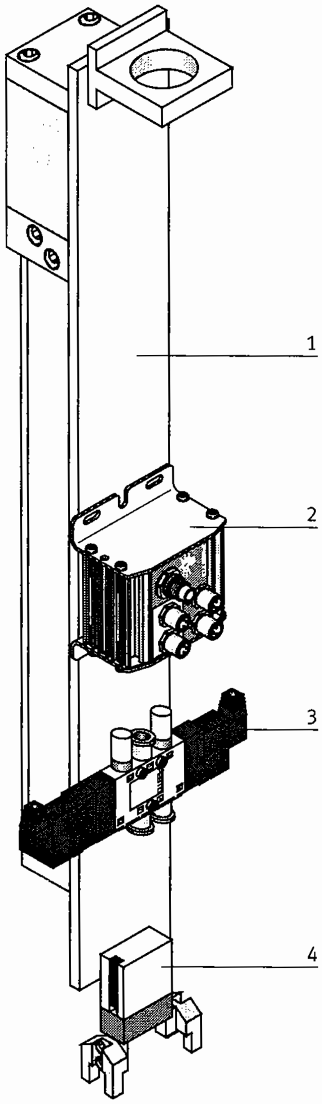


Figure A11.5: Assembling the gripper components

Electrical circuit diagram

The control string of the SPC200 and the two axis interfaces is supplemented with the input-output module. The following items are connected (Figure A11.6):

- the solenoid coils of the double solenoid valves (connected to module outputs)
- the proximity switches (connected to module inputs)

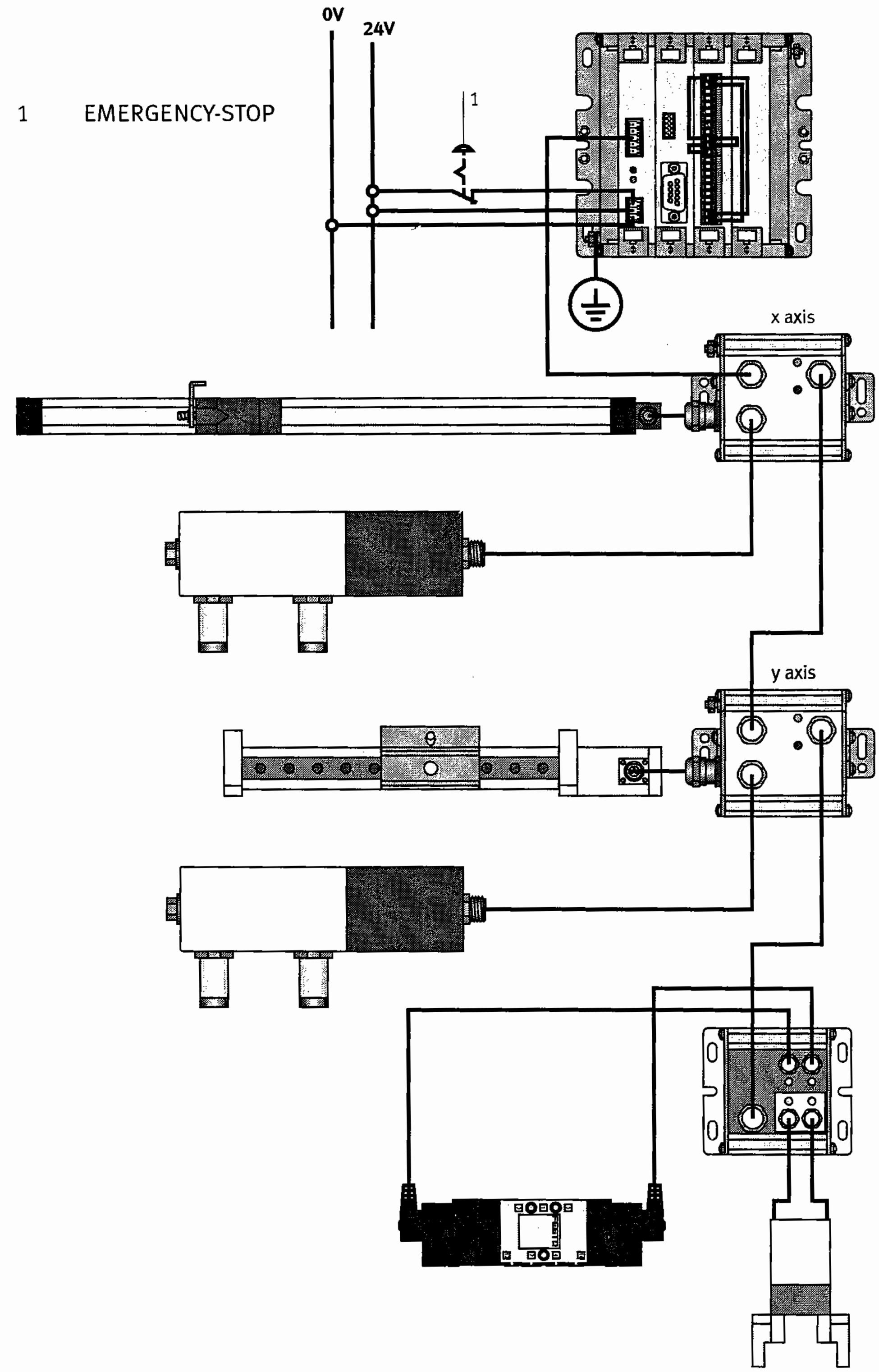


Figure A11.6: Electrical circuit diagram

The inputs and outputs must be connected as shown in Table A11.1.

Input/output of the I/O module	**Connection at gripper end**	**Function**
Output Q 1.0	Solenoid coil of the double solenoid valve	Open gripper
Output Q 1.1	Solenoid coil of the double solenoid valve	Close gripper
Input I 1.0	Proximity switch	Feedback: Gripper open
Input I 1.1	Proximity switch	Feedback: Gripper closed

Table A11.1: Connection of the I/O module

Project configuration via WinPISA
The starting point is a project configured for the twin-axis gantry (see Exercise 9).

The module with the binary inputs and outputs is added to this project. The following entries are required (A11.7):

- Click on "SPC 200", "Insert Object" and "I-O Module" in the Project window
- Choose "SPC-F10-2I/2O"
- Confirm with "OK"

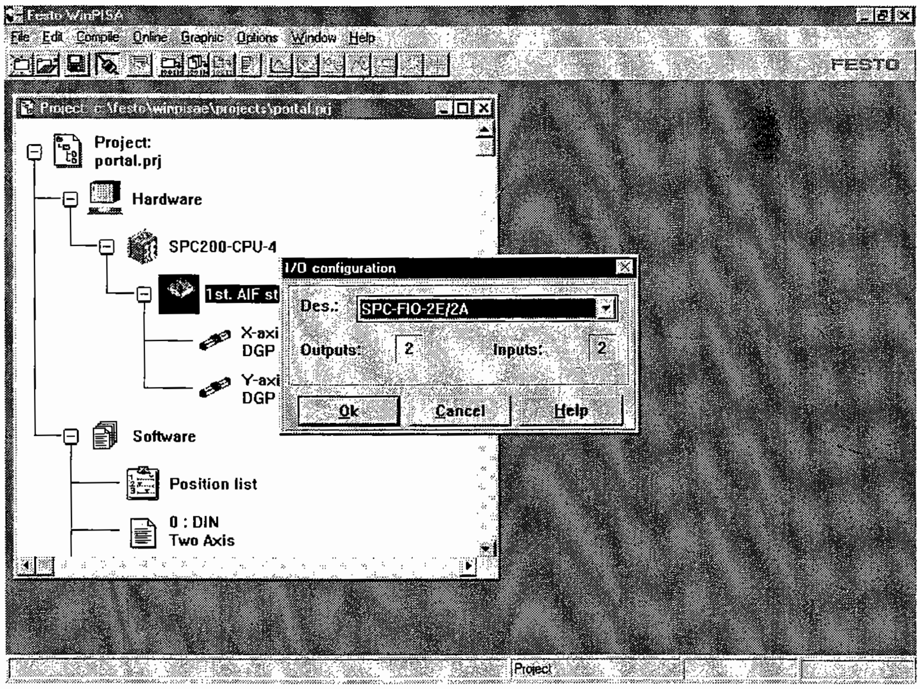


Figure A11.7: I/O configuration

Actuating the gripper

The gripper is controlled via binary outputs. A binary output is set by command "#S" and reset by command "#R".

If the wiring is correct, the following assignment applies in accordance with Table A11.1:

- Output Q1.0 actuates the solenoid for opening the gripper.
- Output Q1.1 actuates the solenoid for closing the gripper.

Figure A11.8 shows an example program for gripper actuation.

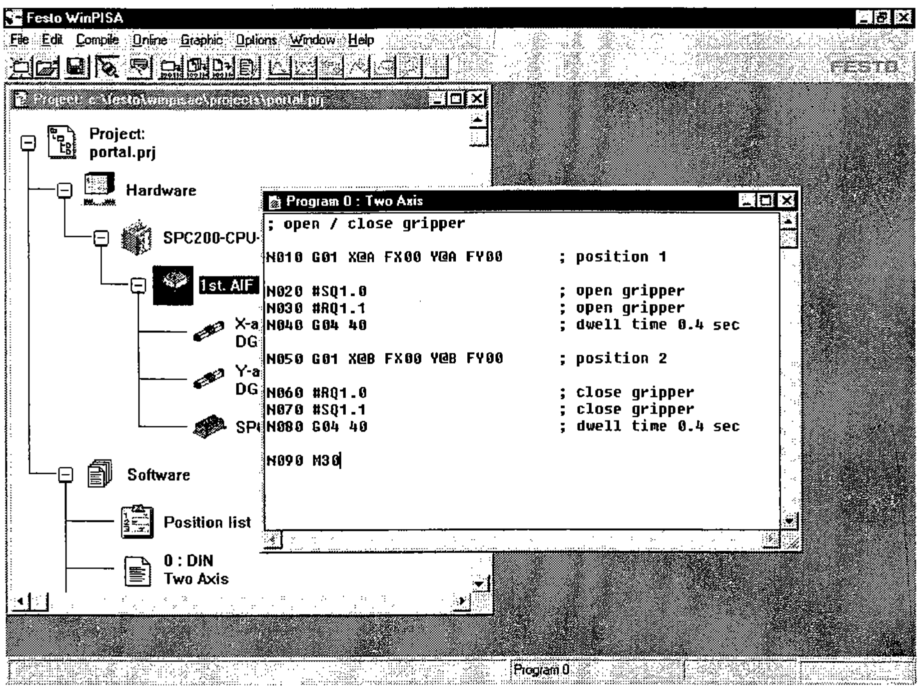


Figure A 11.8: Gripper actuation: Example program

Monitoring the gripper

The following procedures occurs after switching over the outputs for gripper actuation:

- Energising resp. de-energising the solenoid coils
- Switchover of the valve spool
- Build-up resp. relief of the pressure in the cylinder chambers of the gripper
- Movement of the piston to the opposite stop

The next traverse command must not be started until the procedure is fully completed in order to prevent damage to the workpiece and gripper. The following options are available for this:

- Programming a waiting time (Figure A11.8)
- Sensing the proximity switches in the program (Figure A11.9)

Compared to a fixed waiting time, sensing the proximity switches leads to an acceleration of the movement cycle since the system does not wait unnecessarily for the gripper. Consequently, in the case of grippers with proximity switches, this method should be used.

Sensing the proximity switches

The proximity switches are sensed with the following commands (Figure A11.9):

- #T: Tests for logic "1"; branches to the specified NC block if the condition is met
- E05: Unconditional jump; program execution is continued at the specified NC block

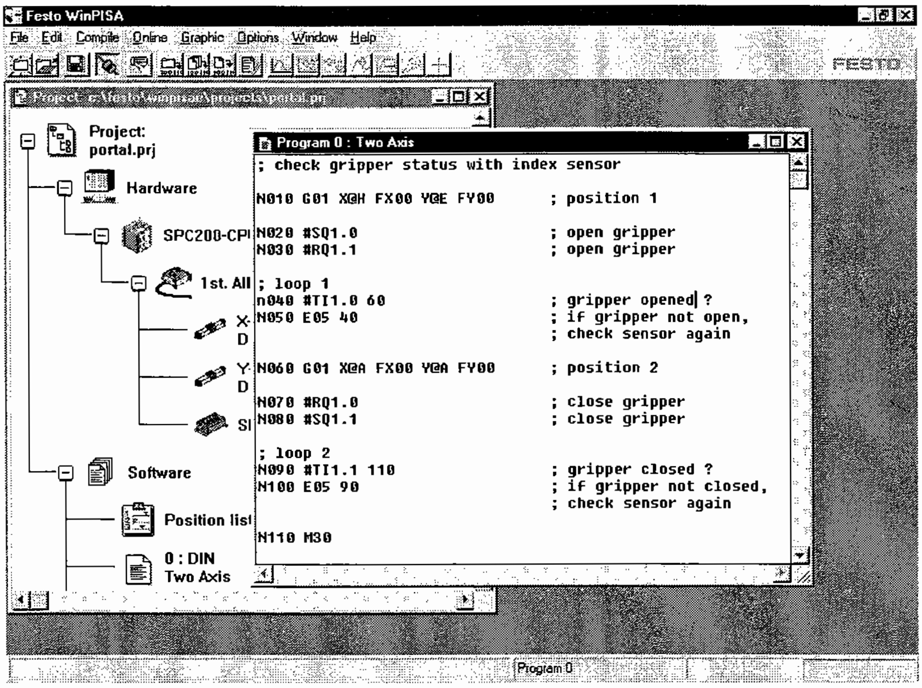


Figure A11.9: Gripper actuation and monitoring: Example program

Problem description

A gantry with two axes has been set up. The function of the two NC axes has already been tested. The next step is to install the gripper and the related pneumatic and electrical components. The overall system must then be put into operation and tested.

Positional sketch

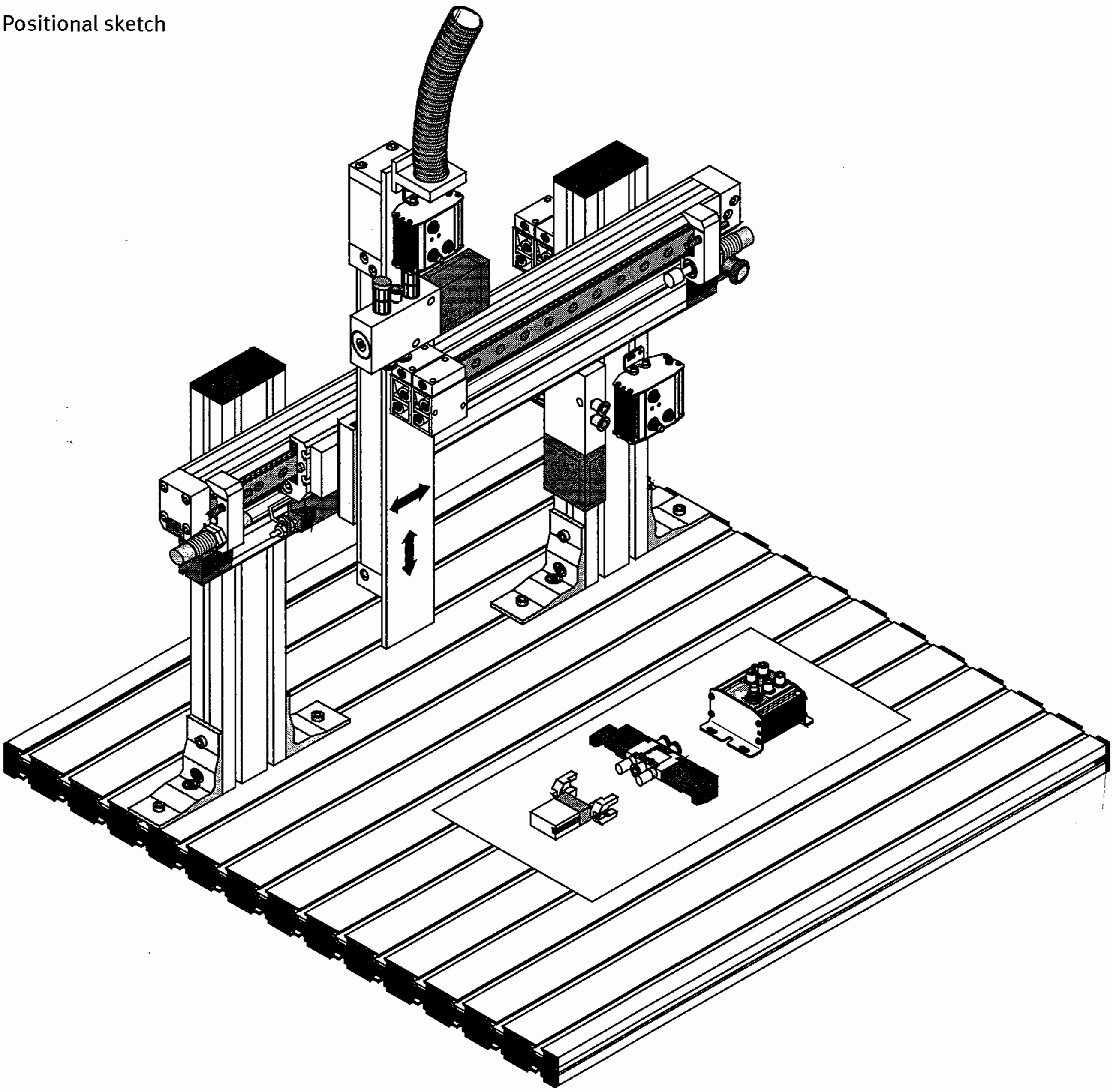


Figure A11.10: Gantry with delivered gripper components

Problem definition

- Mounting the gripper components
- Adding to the pneumatic circuit
- Adding to the electrical circuit
- Commissioning the system

Procedure

The basis for performing this task is a completely set-up, wired two-axis gantry with tubing connected.

1. Assembling the components
Ensure that electrical power supply and compressed air supply is switched off.

Connect the gripper, the double solenoid valve and the module with binary inputs and outputs to the mounting plate of the y axis!

Check whether the y axis can be moved by hand to the bottom stop without the gripper touching down. If the gripper touches down, you must mount the x axis higher.

Caution

In order to mount the x axis higher, you must undo the fixings on the columns. In order to do this, it will be absolutely necessary to first tilt the gantry so that the columns lie flat on the bench!

2. Tubing connection
Tube-up the components in accordance with the pneumatic circuit diagram!

Safety information
When laying the tubing, ensure that none of these project into the traversing range of the two axes.

The tubing routed from the sub-base to the vertical linear axis must be adequately long. Even at the extreme positions of the two axes, the tubing must not be taut or kinked.

Check the tubing layout by moving both axes by hand as far as the stops. If necessary, correct the tubing arrangement.

3. Setting up the electrical circuit
Make the electrical interconnection as shown in the connection diagram (Figure A11.6, Table A11.1). Use the Festo Didactic 24 V power pack as the power supply. Test whether both axes can be moved by hand as far as the stops. If one or more cables are too short, correct the arrangement of the axis interface and/or valves in question.

4. Routing of cable and tubing
Ensure that the split conduit is placed around cable and compressed air lines leading to the y axis.
The split conduit may neither chafe nor knock against other items when the axes move. Check this by moving the slides of both axes by hand!
No cables or tubing must be routed in the traversing range of the gantry!
Owing to the high acceleration and deceleration forces, it is practical to also secure by means of clips, any tubing and cables hanging in bends or loops.

5. Attaching the gantry
Both axes are traversed with high force and at high speed. The slotted assembly board must thus be firmly clamped or screwed to a sturdy base!

6. Checking the set-up
- Does the arrangement correspond to the positional sketch?
- Are all screws firmly tightened?
- Can the slides of both axes be moved by hand between the stop positions preset by the shock absorbers?
- Can the vertical axis be slid as far as the bottom stop without the gripper touching down?
- Slide the vertical axis to the bottom stop. Can the horizontal axis be slid throughout the entire motion range without the vertical axis or the gripper colliding with components secured to the sub-base?
- Is all tubing firmly attached?
- Are all plugs firmly attached?
- Can both axes be slid to the stops without the cable or tubing being taut or kinked?
- Ensure that there are no wires or tubing crosswise over the linear unit (risk of shearing off)
- Do the circuits correspond to the circuit diagrams?
- Is the sub-base secured firmly to the base?

7. Test programs for gripper actuation
Write a test program which opens the gripper, and then compile and test the program. Adjust the corresponding proximity switch so that it responds when the gripper is opened.

Caution

Switch off the electrical power supply and compressed air before carrying out assembly work!

Write a test program that closes the gripper and then compile it and test it. Adjust the corresponding proximity switch so that it responds when the gripper is closed.

8. Test program for gripper monitoring
Write a program that performs the following operations consecutively:

- Approach to point (50, 100)
- Open gripper
- As soon as the gripper is open, approach to point (50, 200)
- Close gripper
- As soon as gripper is closed, approach to point (150, 200) and to point (50,200)

Compile the program and test the functions of program and system. If necessary, you will need to correct and retest the test program and/or set-up.

Exercise 12
Packing accessory parts for flat-pack furniture

Training aim

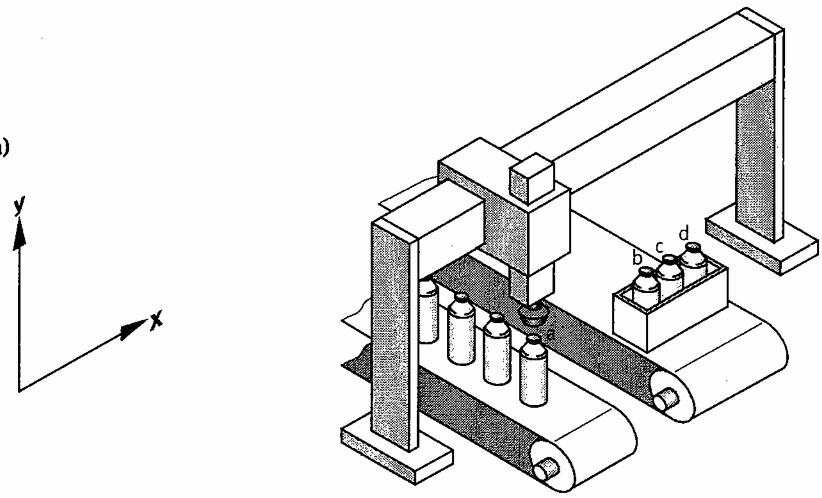
- To be able to program a motion sequence for the gantry with gripper
- Familiarising yourself with skipping positions
- Familiarising yourself with subroutines

Technical knowledge

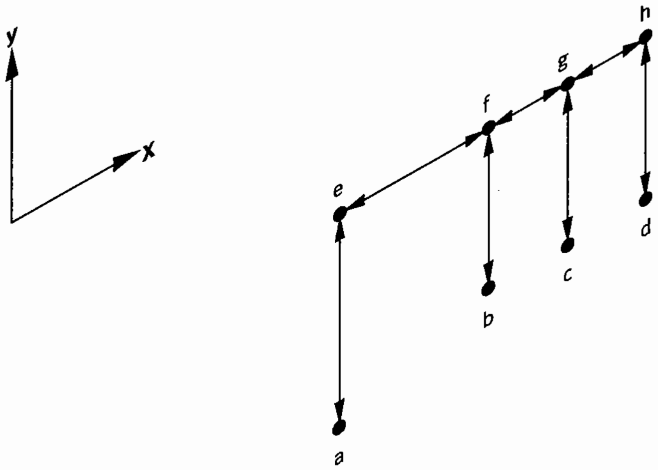
Skipping positions: Application
Figure A12.1 shows a packing device.

- Positions a, b, c and d must be approached precisely.
- Positions e, f, g and h are inserted in the movement operation so that the jars are lifted vertically or deposited vertically. Precise approach to these positions is not required. They can be skipped. This greatly speeds up the movement cycle.

a)



b)



c)

	x/mm	y/mm
a	100	100
b	250	150
c	350	150
d	450	150

	x/mm	y/mm
e	100	350
f	250	350
g	350	350
h	450	350

Figure A12.1: Skipping positions: Application

Skipping positions: Example program

Skipping is performed with command G25 (see example program, Figure A12.2).

- NC blocks 1 and 2:
  The two positions are approached precisely.
- NC block 3:
  Step enabling condition from the next NC block to the next NC block but one is set to 85 % of the movement of the y axis.
- NC block 4:
  NC block 5 is started as soon as the y axis has travelled 85 % of the path to the position (100,200).
- NC block 5:
  The step enabling condition for the next NC block to the next NC block but one is set to 95 % of the movement of the x axis.
- NC block 6:
  NC block 7 is started as soon as the x axis has travelled 95 % of the path to the position (250, 200).
- NC block 7:
  The position (250,50) is approached precisely, i.e. without skipping.

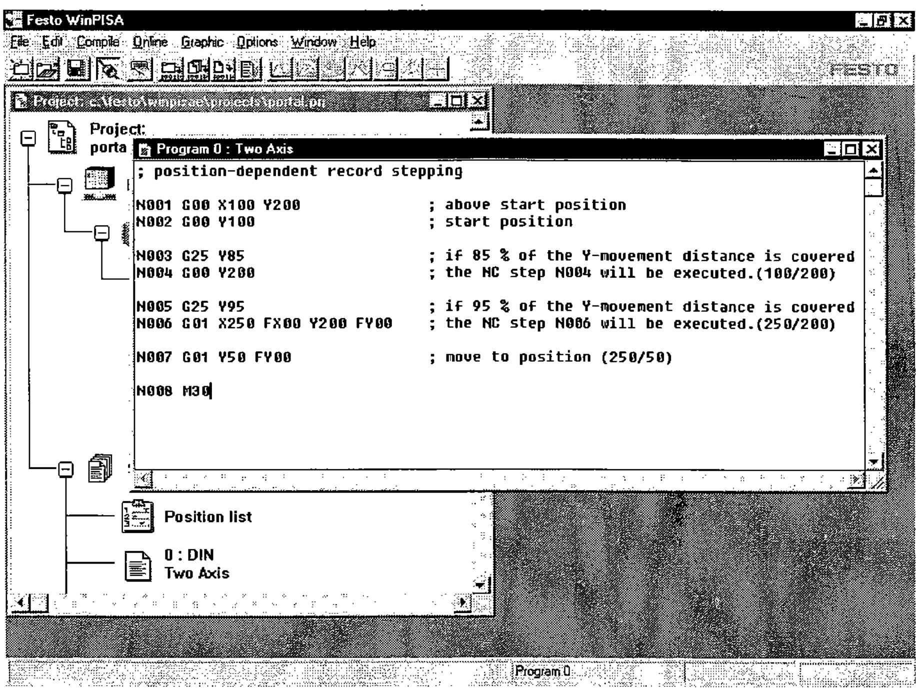


Figure A12.2: Skipping positions: Example program

Application of subroutines

Extensive control problems are generally not handled with a single program but by a main program in conjunction with one or more subroutines. The subroutines are called by the main program.

Using subroutines offers the following advantages:

- The task is structured and dissected into job steps. The overall program becomes clearer.
- Program parts required more than once at different points need be written only once. This shortens the overall program.

Creating subroutines

Only one program, the main program (program 0), has been created so far in a WinPISA project.

Each subroutine is saved separately in the project. A new subroutine is created in WinPISA as follows:

- Click on the Software icon in the Project window
- Choose command "Insert Object" in the "Edit" menu
- Enter the program title and program number in the "New Program" dialog box (each number can be issued only once per project)
- Insert an explanatory text in the Description field
- Confirm your entry with "OK"

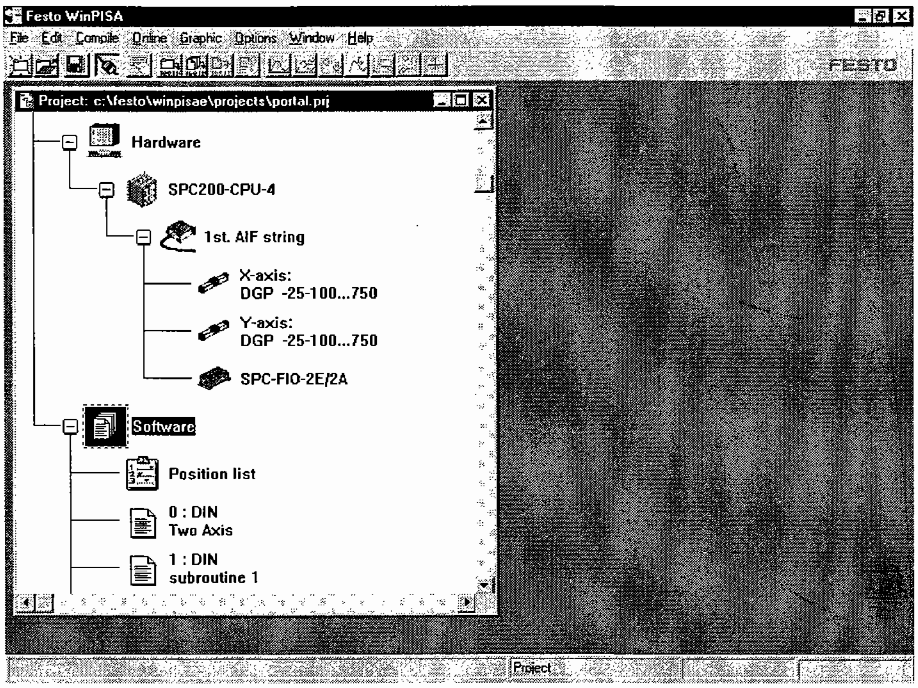


Figure A12.3: Project with main program and one subroutine

Structure of a subroutine

A subroutine consists of a string of NC blocks. A subroutine ends with command M02 (return to calling main program).

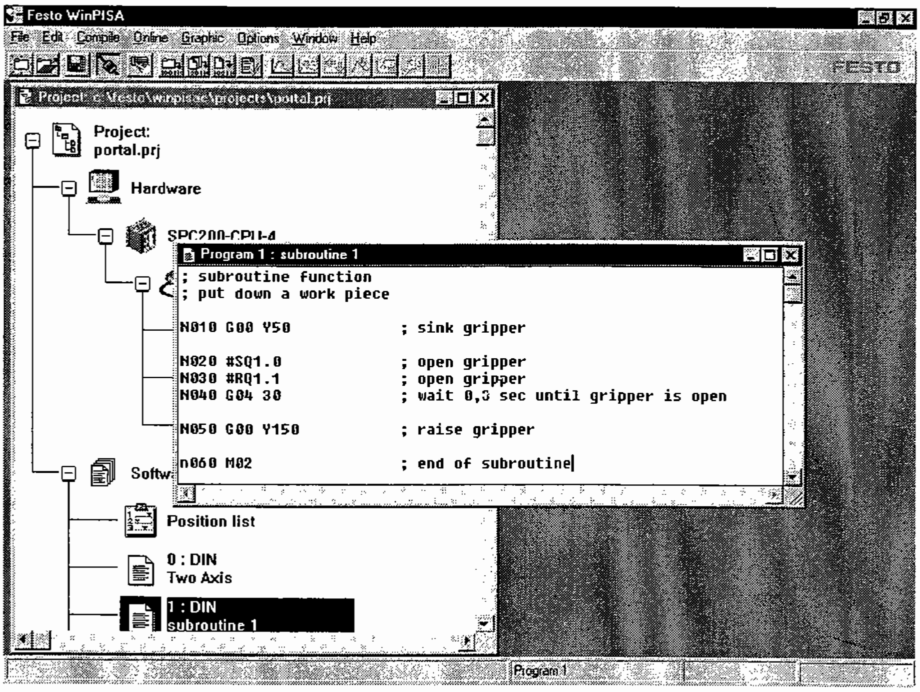


Figure A12.4: Subroutine: Example

Calling subroutines

A subroutine is called with command L and the program number.

The example program (Figure A12.5) calls subroutine 1 (Figure A12.4) ten times consecutively. The commands of the main program have the following significance:

- #LR: Load register with required number of subroutine calls (in this case: 10 calls in register 0)
- L: Call subroutine (in this case: Call subroutine 1)
- AR: Add registers (in this case: decrement the content of register 0 by 1)
- TR: Test register (in this case: test register value for 0)
- E05: Unconditional jump (in this case: Jump to start of loop if register value is not equal to zero, further subroutine call)
- If register value equals 0: Continue the program run after loop

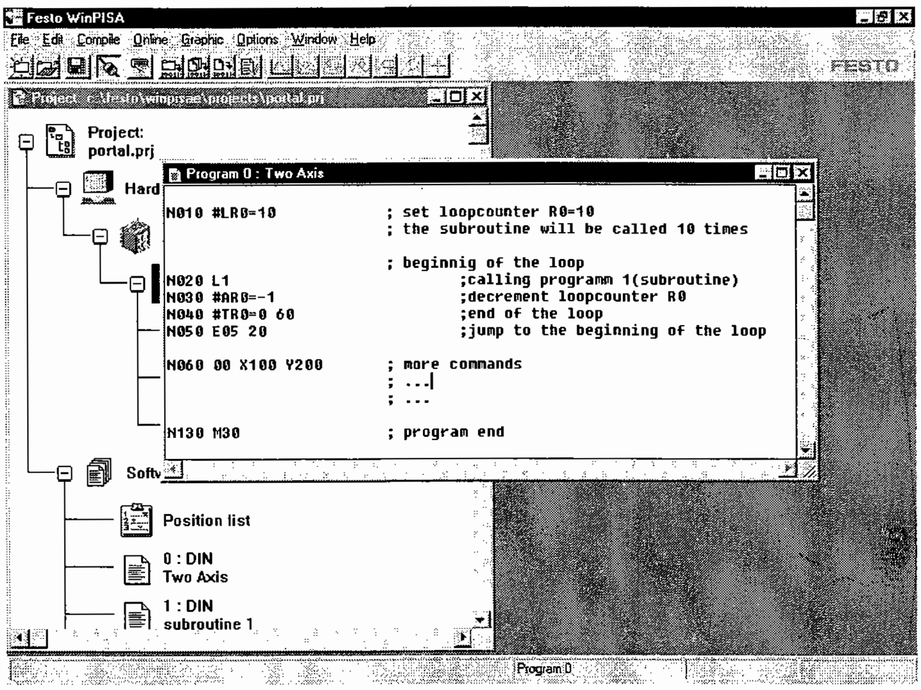


Figure A12.5: Main program with subroutine call (excerpt)

Problem description

Assembly parts must also be supplied in the case of flat-pack furniture. The following parts are required for a cabinet:

- 8 screws
- 8 corner connectors
- 12 shelf holders
- 4 door hinges

The parts are packed in an accessory pack carton for each furniture item. A gripper fetches one part at the corresponding feed point and places it in the accessory pack carton.

Positional sketch

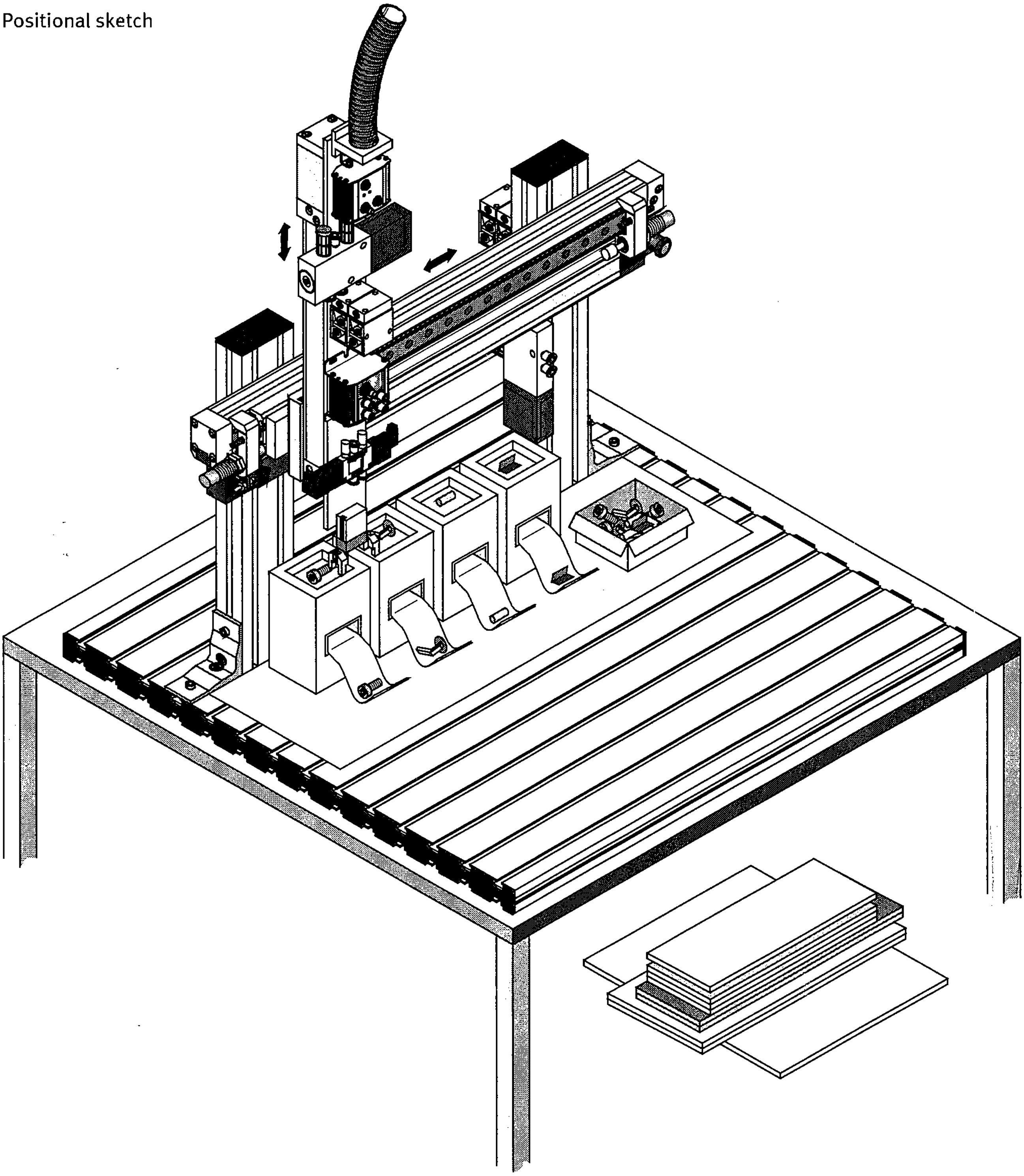


Figure A12.6: Positional sketch

Problem definition

- Creating and configuring the project
- Writing the motion program
- Testing the motion program
- Optimising the traversing speed

Procedure

1. Create the project
Create a project named "Package"!

2. Configure the hardware
Configure the project!

3. Program design and test
Write the NC program for the packaging device (Figure A12.6, positions to be approached: See Table A12.1).

Use the following 4 subroutines:

- Subroutine 1: Pack a screw
- Subroutine 2: Pack a corner connector
- Subroutine 3: Pack a holder
- Subroutine 4: Pack a door hinge

Position	Designation	x axis	y axis
a	Pick-up position, screws	50	50
b	Pick-up position, connectors	120	50
c	Pick-up position, hinges	190	50
d	Pick-up position, hinges	260	50
e	Deposit position	390	70
f	Above pick-up position, screws	50	200
g	Above pick-up position, connectors	120	200
h	Above pick-up position, holders	190	200
i	Above pick-up position, hinges	260	200
k	Above deposit position	390	200

Table A12.1: Positions for project "Package", "Package1"

Compile and test the program until it runs error-free!

4. Program optimisation
Optimise the movement cycle by skipping points f, g, h, i and k! Write a new project Package1 for this!

Part B

Part B Fundamentals

1. Drives for automation technology

1.1 Areas of application of pneumatics in automation technology

Pneumatics is used in automation technology for the following functions:
- Detection of process statuses by means of sensors
- Information processing (e.g. using pneumatically actuated valves)
- Triggering of actuators by means of final control elements (valves)
- Execution of work functions with actuators (e.g. cylinders and rotary cylinders).

Most frequently used pneumatic components are final control elements and actuators.

1.2 Areas of application of drives in automation technology

In automation technology, drives are used for the following areas of application, including amongst others:
- Machining (e.g. with lathes and milling machines)
- Forming operations (e.g. with presses, bending devices for sheet metal)
- Assembly and fitting of components (e.g. fitting of printed circuit boards with electronic components)
- Handling (e.g. removal of workpieces from a machine tool, insertion of workpieces into a press)
- Process technology (e.g. the acutation of flaps and valves)

Handling technology forms the main area of applications for pneumatic drives.

In automation technology, it is necessary to execute both linear and rotary/swiveling motions. Fig. 1.1 shows a pneumatic linear cylinder and a pneumatic rotary actuator.

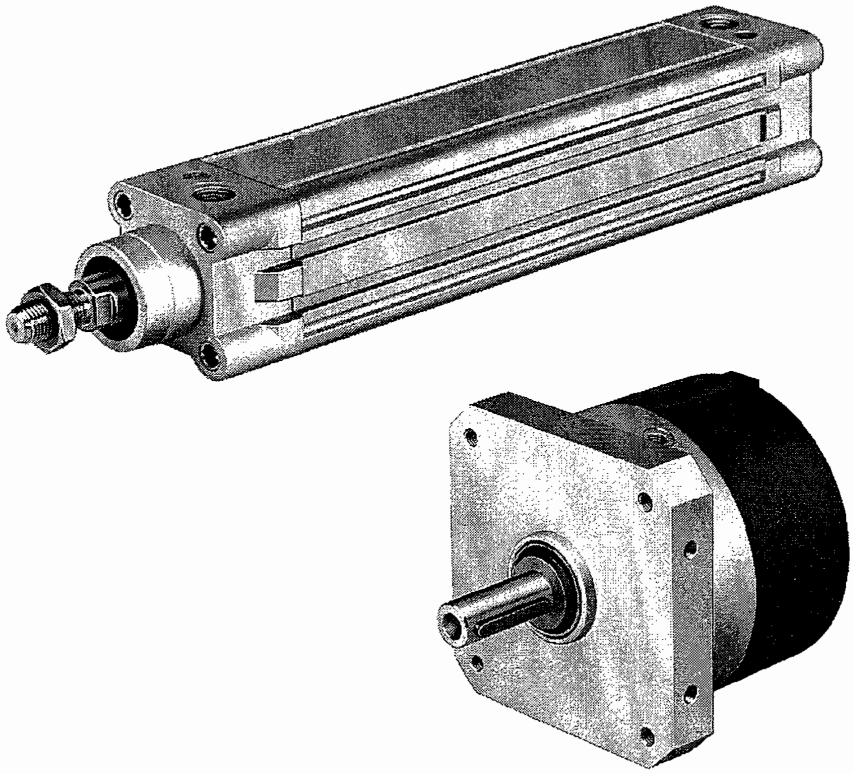


Fig. B1.1: Pneumatic linear cylinder and pneumatic rotary actuator

Benefits of pneumatic cylinders

Pneumatic cylinders have the following benefits over other types of drives:

- Low-priced
- Low weight and relatively low space requirement
- Easy to install
- Simple, robust design
- Available in numerous different sizes and designs
- High traversing speed
- Explosion-proof

1.3 Double-acting cylinder drive with end-stop positioning

A double-acting pneumatic cylinder drive is generally actuated by a switching valve and positioned against two stops. In order to permit long service life to be achieved, the impact of the cylinder against the stops must be cushioned.
There are two possible methods of achieving cushioning:

- using cylinders with end-position cushioning
- by fitting shock absorbers

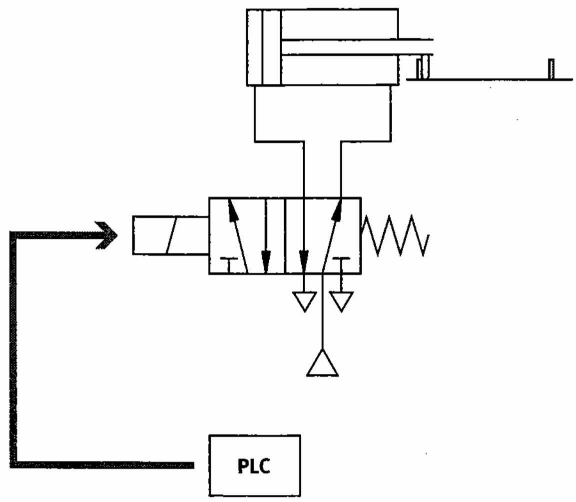


Fig. B1.2: End-stop positioned electro-pneumatic cylinder drive

The following limitations must be observed:

- This type of drive can be used only when no more than two positions need to be approached.
- If the distance between the two positions needs to be changed, the stops must be re-positioned or the cylinder must be replaced by another cylinder with a different stroke.

Typical applications for end-stop positioned cylinders, for example, ejection of workpieces from a magazine or stamping of a series of identical workpieces.

1.4 Servo-pneumatic cylinder drive

A pneumatic NC axis is equipped with a servo-pneumatic drive (Fig. B1.3). It consists of the following components:

- Controller and position controller
- Valve
- Cylinder
- Measuring system.

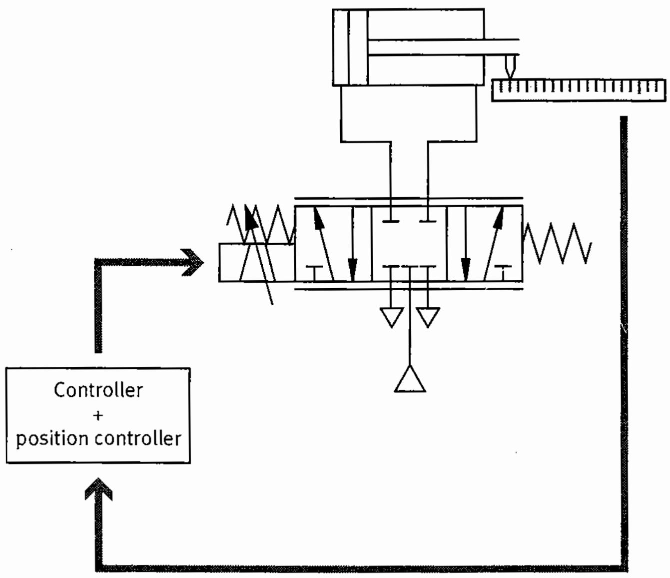


Fig. B1.3: Servo-pneumatic cylinder drive

The design and mode of operation of a servo-pneumatic drive are described in further detail in Chapters B2, B4, B5, B6.

Benefits of servo-pneumatic drives

Servo-pneumatic drives provide two major benefits over end-stop positioned cylinder drives:

- Any desired position can be approached.
- No conversion is required to enable the drive to be used for different applications. It is only necessary to re-write the motion program for the drive in question. This type of drive is accordingly a freely-programmable drive.

Applications for servo-pneumatic drives

Typical applications for servo-pneumatic drives are:
- Fitting electronic components on printed circuit boards
- Palletising
- Assembly of components (e.g. miniature gearboxes)
- Handling of workpieces (e.g. the insertion of various workpieces into a press)

The maximum power output of servo-pneumatic drives is relatively low (generally less than 1 kW). Their main applications are therefore in cases where only small loads need to be moved (typically between 1 and 20 kg).

Application example for a servo-pneumatic cylinder drive

A typical application for servo-pneumatic drives appears in Fig. 1.4.
The illustrated handling device shows 3 pneumatic NC axes. The three axis directions are designated as x, y and z. The x and y axes move horizontally, while the z axis moves vertically. The device is driven servo-pneumatically and is used to place workpieces on a pallet.

An application of this kind could not be implemented with switching valves and fixed stops, since more than two positions need to be approached in all three directions.

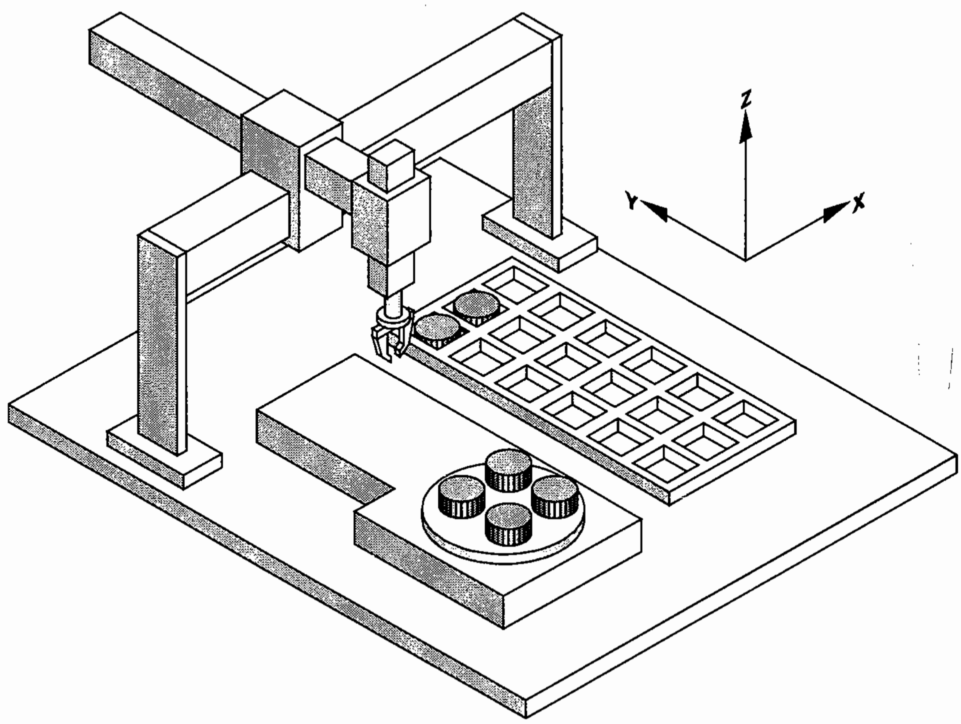


Fig. B1.4 Palletising with a three axis handling device

1.5 Electrical and hydraulic positioning drives

In addition to servo-pneumatic drives
- electrical stepper motors
- electrical servo motors
- hydraulic servo drives

can also be used as freely-programmable positioning drives.

Electrical stepper motors

Stepper motor drives are used for handling applications. The electrical stepper motor generates a rotary motion. In conjunction with a gear unit (spindle or toothed-belt), stepper motor drives can also be used as linear drives. The motions produced in this way will tend to be slower and less powerful than those of other freely-programmable drives. On the other hand, the overall cost, including a controller, is relatively low.

Servo-pneumatic drives have the following benefits compared to electrical stepper motors:
- Higher operating speed
- Lower weight
- Simpler design, since, in the case of linear drives, there is no gearbox

Electrical servo motors

Electrical servo drives are exclusively used where rotary motions are required (e.g. drives for robot arms) and/or high accuracy must be maintained even when the drive is subjected to higher loads (e.g. machine tools).

Stepper motor drives are also used in conjunction with toothed-belt or rack-and-pinion drives to generate linear motions in handling systems.

In comparison with a servo-pneumatic drive a freely programmable drive is
- of simpler design
- considerably less expensive

Servo-pneumatic cylinder drives are thus the more economical choice for applications requiring linear drives with high traversing speed combined with good positioning accuracy.

Servo-hydraulic drives

Servo-hydraulic drives are used in all cases requiring motions with extremely high force or extreme dynamics. These drives are of complex design and are relatively expensive. Examples of applications include:

- Drives for production machines where high force and performance are required (presses, die-casting machines, etc.)
- Actuation of wing flaps, tail flaps and rudders of aircraft

Servo-pneumatic drives are used only in cases requiring relatively low force and power (generally less than 1 kW). Servo-hydraulic drives, on the other hand, are used when high force and performance are needed. There is thus no overlap between the areas of application of the two types of drives.

2. Motion characteristics of a servo-pneumatic drive

2.1
Approach to a new position: End-stop positioned pneumatic drive

Fig. B2.1 shows the reaction of an end-stop positioned cylinder drive to a reversal of the switching valve. The illustration shows the piston position as a function of time.

- At the start of the curve, the piston is positioned against the left-hand stop (position A).
- At the point in time t1, the switching valve is actuated by a programmable logic controller (PLC). This causes the left-hand chamber of the cylinder to be pressurised and the right-hand chamber to be exhausted. The pressure in the left-hand chamber increases, while the pressure in the right-hand chamber decreases. An imbalance of forces is thus created at the piston.
- The piston travels to the right-hand stop (position B).
- Cushioning is effected by means of the end-position cushioning or a shock absorber.

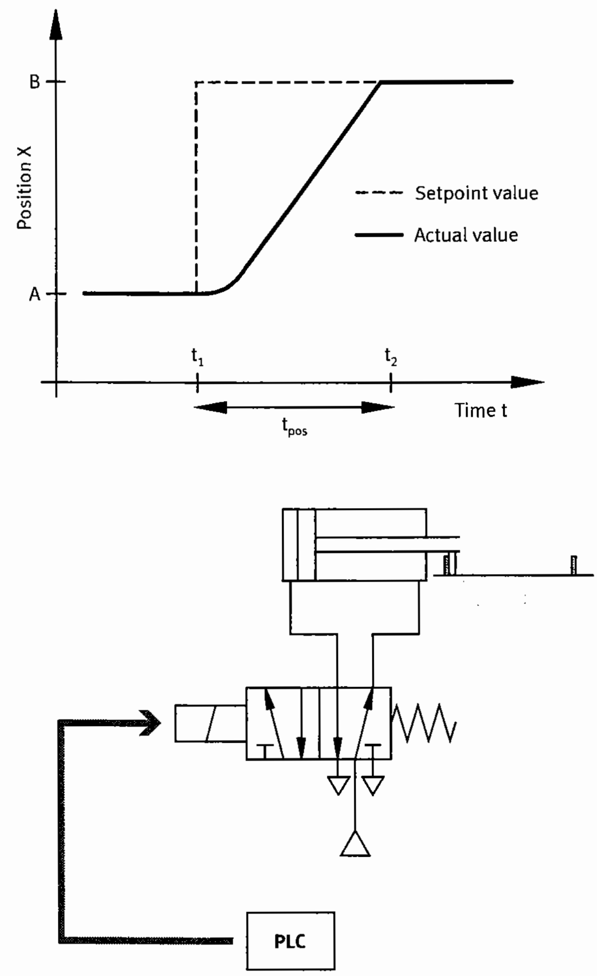


Fig. B2.1: Motion sequence of an end-stop positioned drive

2.2
Approach to a new position: Servo-pneumatic cylinder drive

In the case of a servo-pneumatic drive the controller issues the reference or setpoint position of the piston rod. The setpoint position is input to the position controller as a numerical value. In the position controller, the setpoint position (guide variable) is compared with the actual position of the piston rod (controlled variable). The control signal for the valve is derived from this result.

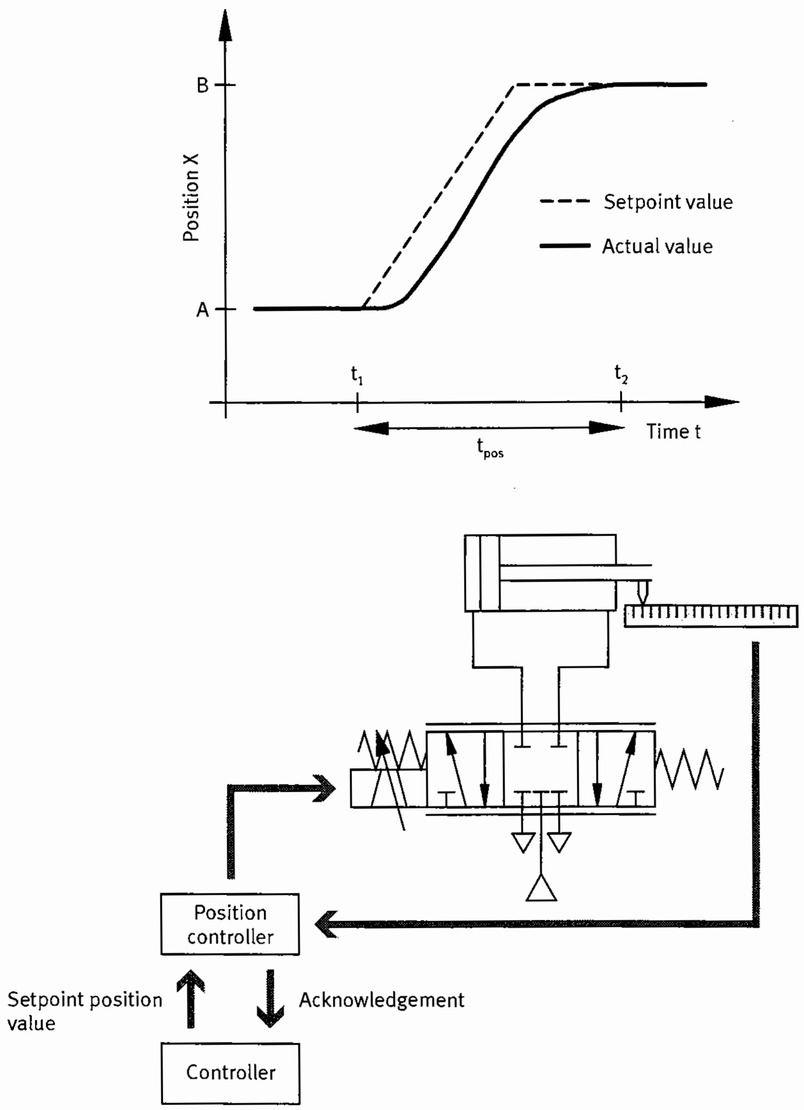


Fig. B2.2: Motion sequence of a servo-pneumatic drive

Fig. B2.2 shows the motion characteristic of a servo-pneumatic drive. Positions A and B are not at the piston rod stops but part-way along the travel path. The setpoint position is shown as a dotted line, the actual position as a solid line.

- At the start, the setpoint and actual positions have the value A. The valve is closed. The piston rod is in the position shown.
- The value of the setpoint position changes from A to B. The valve is actuated by the position controller in such a way that the left-hand cylinder chamber is pressurised and the right-hand chamber is exhausted. An imbalance of forces is created at the piston.
- The piston rod moves to the right, thus reducing the difference between the setpoint position and actual position. The piston position is measured continuously and fed to the controller. The controller detects that the system deviation is becoming smaller and modifies the valve actuation.
- The piston rod is brought to a halt in good time by the application of pressure to the right-hand cylinder chamber. This retardation process is considerably gentler than in the case of a drive positioned by means of stops.
- At the point in time t2, the deviation between the setpoint position B and the actual piston-rod position is less than the specified tolerance threshold. The position controller signals to the master controller that the new position has been reached.

Positioning accuracy

The tolerance threshold is specified by the user as appropriate to the positioning accuracy which is required. The value generally lies between 0.1 and 1 mm.

Positioning time

Typical values for the positioning time tpos (ref. Fig. B2.2) lie between approx 0.25 and 1 s, depending on the positioning stroke, mass load and required accuracy.

An example of applications with relatively low accuracy requirements is palletising (Fig. B1.4). Here an accuracy of 1 mm is often sufficient. Positioning times between 0.25 and 0.3 s can be achieved with short strokes.

The closed-loop method of controlling servo-pneumatic positioning drives is described in further detail in chapter B6.

2.3 Reaction of a pneumatic cylinder drive to interference forces

External forces may act on a pneumatic cylinder drive. This is the case, for example, when a weight acts on a vertical positioning drive (Figs. B2.3 and B2.4).

End-stop positioned cylinder drive

The piston of an end-positioned cylinder drive is pressed with full force against the stop as soon as its motion is complete. As long as the force acting on the piston rod side is less than that on the piston side, the piston will remain on the stop.

Servo-pneumatic cylinder drive

In contrast to the case of the end-stop positioned cylinder drive, a servo-pneumatic cylinder drive must have high stability with respect to loads, even when the piston is not resting on the stop. In this case, the piston is supported not by the hard stop but by a floating air (pressure) balance.

Load stability of a pneumatic cylinder drive with closed control valve

We will first consider the load stability of a pneumatic cylinder drive with a closed control valve.

- The drive is initially unloaded (Fig. 2.3a).
- A load is then applied to the piston rod. The control valve remains closed (Fig. B2.3b).

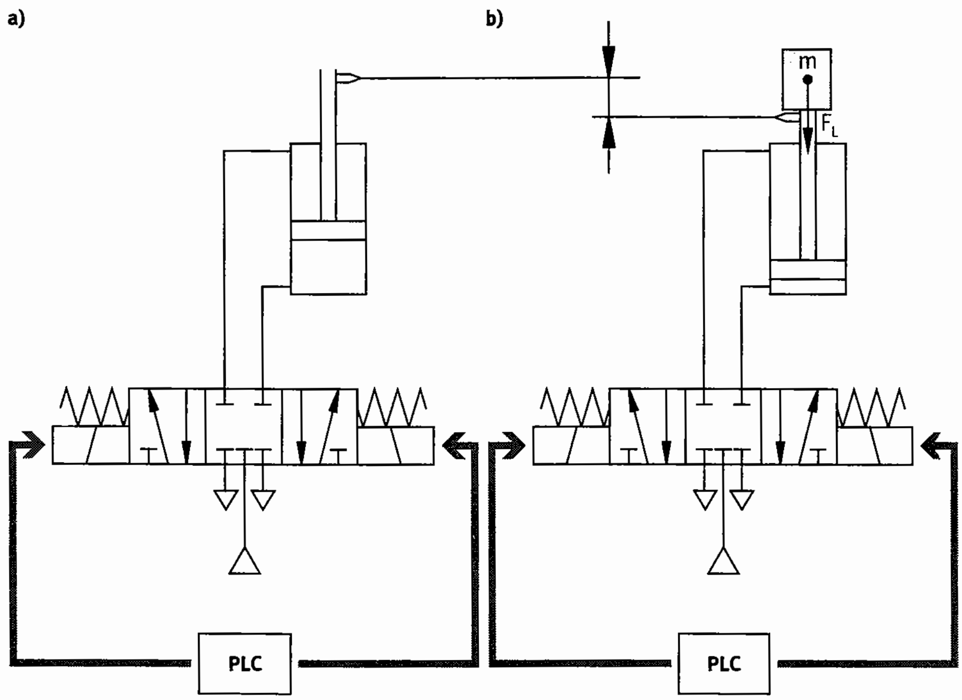


Fig. B2.3: Load stability of a pneumatic drive with closed control valve

Since the air in the cylinder chambers is compressible, the action of the force causes the column of air in the lower chamber to be compressed, while the column in the upper chamber expands. The downward motion of the piston is clearly visible. Instability of this kind with regard to loads is not acceptable for practical applications.

Load stability of a servo-pneumatic drive actuated via closed-loop control

Fig. B2.4 shows the behaviour of a servo-pneumatic drive. If an interference force acts on the piston, this will initially cause the piston to be moved slightly away from its reference position. This produces a system deviation. The drive controller detects this deviation and provides compensation for the interference force by appropriate triggering of the valve

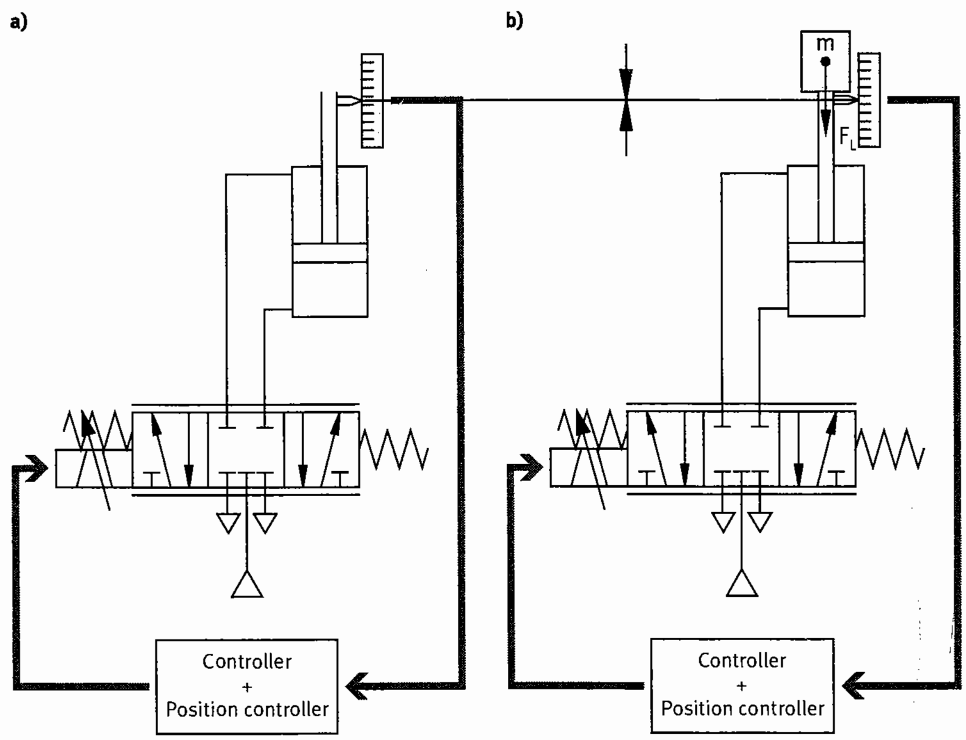


Fig. B2.4: Load stability of a pneumatic drive with closed-loop control

Due to the corrective action of the position controller, the rigidity under load of a cylinder drive with high-quality position control is considerably better than that of a cylinder drive whose valve is simply kept closed. The deviation resulting from applied loads is, in the case of a cylinder drive with closed-loop control, less than one hundredth of the deviation that occurs with a cylinder without closed-loop control.

Even if high forces act on the piston rod, e.g. equal to half of the maximum cylinder force, the cylinder piston will fall by only a very small distance, typically approx. 0.1 mm (Fig.B2.4). This small deviation cannot be seen on the scale chosen for the illustration.

In view of this high rigidity under load, an additional holding brake will not be necessary for most handling applications.

2.4 Table comparing an end-stop positioned drive and a servo-pneumatic drive

The major differences between an end-stop postioned pneumatic drive and a servo-pneumaric drive are summarised in table B2.1.

	End-stop postioned drive	**Numerically controlled drive**
Signal specification	valve actuating signal	position
Signal type	binary	digital
Number of approachable positions	2	approx. 4000 to 200,000
Valve	switching valve	dynamic control valve
Displacement measuring system	no	yes
Closed-loop control	no	yes

Table B2.1: Characteristics of an end-stop positioned drive and a servo-pneumatic drive

2.5 Influence of valves and closed-loop control

A servo-pneumatic cylinder drive with closed-loop control is used for the following tasks:

- for the approach of a piston to a specified setpoint position, to an accuracy of a fraction of a millimetre
- to enable a position to be approached rapidly and without overshoot
- to ensure high stability with cyclical loads

These requirements can be met only by using a closely matched position controller and a suitable valve. The mode of operation of the valve and the controller are described in Chapters B4 and B6.

3. Applications of pneumatic NC axes

3.1
Design of a pneumatic NC axis

The abbreviation „NC“ in the term „NC axis“ stands for „Numerical control“. In case of a numerically controlled axis, the position which the axis is to approach is specified by the controller as a number. A pneumatic axis consists of the following components (Fig. B3.1):

- a linear guide (1) and a slide (2)
- a drive cylinder (3) (in the illustration, a rodless cylinder)
- a dynamic valve (4)
- a displacement encoder (5)
- a controller and positioning unit (6) with axis interface (axis interface, 7)

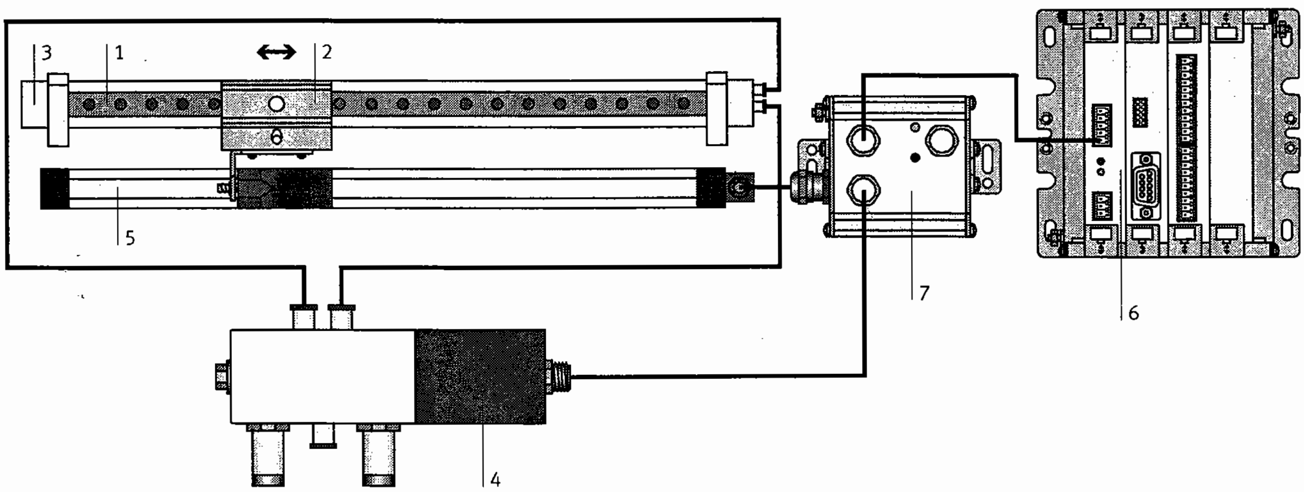


Fig. B3.1: Components of a servo-pneumatic NC axis

Fig. B3.2 shows two linear axes with the same cylinder stroke.

- a linear axis with a piston rod cylinder
- a linear axis with a rodless cylinder.

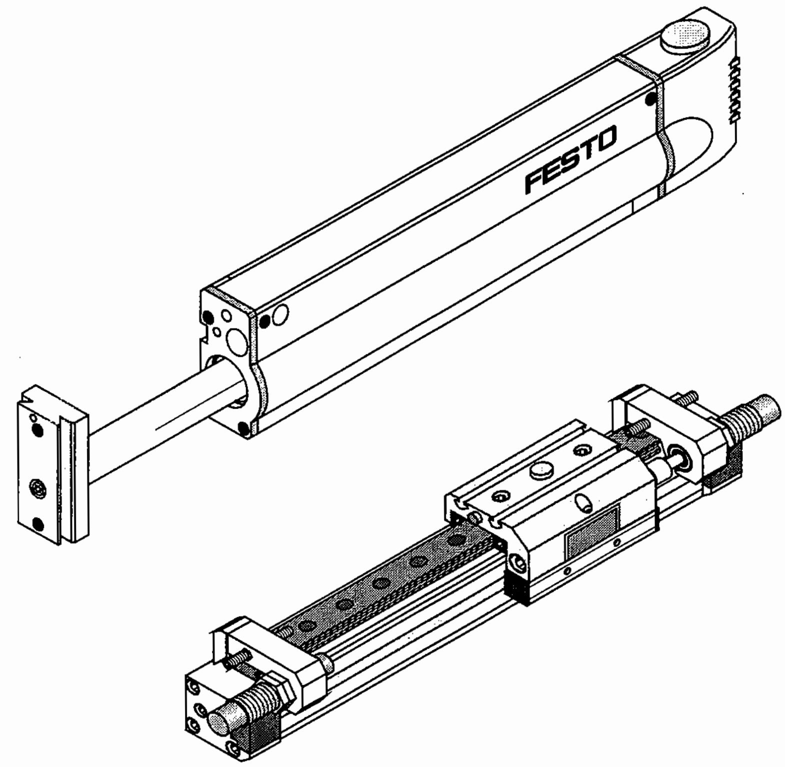


Fig. B3.2: Linear axes with piston rod and rodless cylinders

With identical cylinder stroke, the installation length of the axis with the rodless cylinder is considerably shorter. Hence, it is easier to install into a system. For this reason, rodless cylinders are the main type used for NC axes.

The following application examples refer only to axes with rodless cylinders, such as are used in the present function package.

Application example for a single pneumatic NC axis

Fig. B3.3 shows an example of an application for a single pneumatic NC axis. The servo-pneumatic drive operates a chute which is used to sort packages arriving on a program controlled conveyor belt, and distribute these to three different conveyor belts.

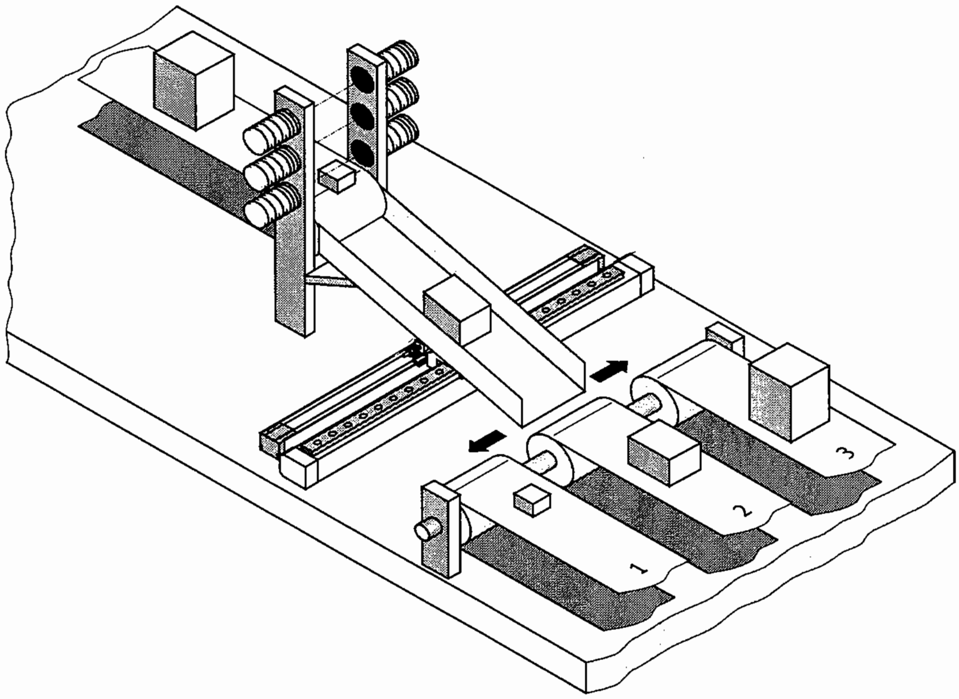
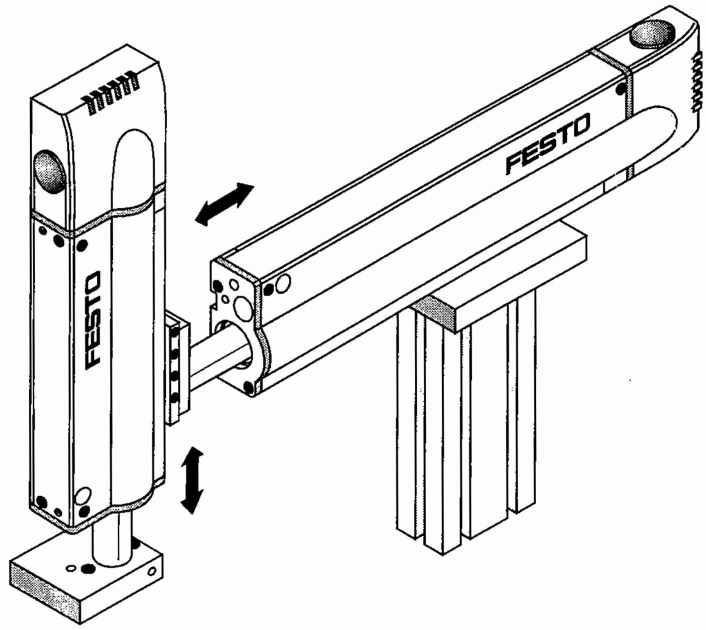


Fig. B3.3: Sorting device for pneumatic NC axis

3.2 Combination of two pneumatic NC axes

For many applications it is necessary to move a tool or workpiece in several directions. In cases of this kind, combinations of two or three servo-pneumatic axes are used. The axes can be linked to the next linear unit by means of either their endpieces or the slide. Fig. B3 shows two possible axis combinations.



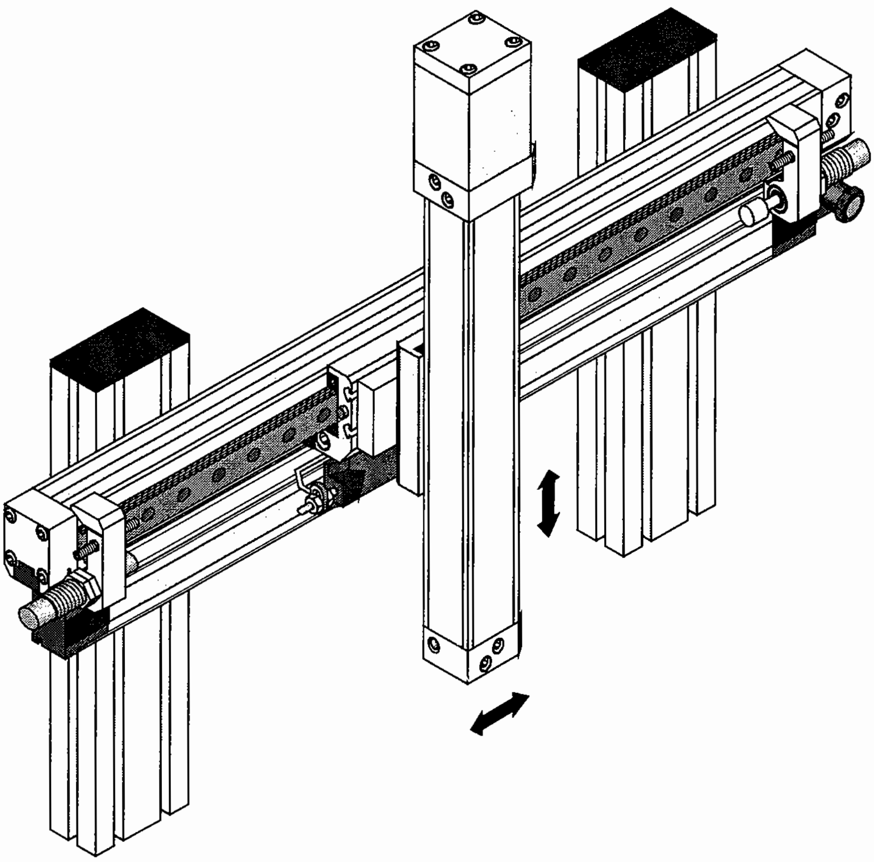


Fig. B3.4: Linear axis combinations

Two axis handling device

Fig. B3.5 shows a two axis handling device. The first axis is fitted to a gantry frame by its two end pieces. The two axes are linked together by means of their slides. The lower end of the second axis is fitted with a vacuum suction cup to allow workpieces to be gripped or picked up by vacuum.
Sequence of the motion cycle as follows:

- The gripper is brought to the workpieces (z axis moves downwards).
- The workpiece is gripped.
- The z axis and workpiece are moved upwards.
- The x axis moves (positive x direction).
- The z axis moves downwards.
- The workpiece is set down.
- The z axis moves upwards.
- The x axis returns to its initial position (negative x direction).

Following, the cycle for the next workpiece begins.

A device of this kind can, for example, be used to sort bottles arriving on a conveyor belt into a packaging unit (see Fig. B3.5).

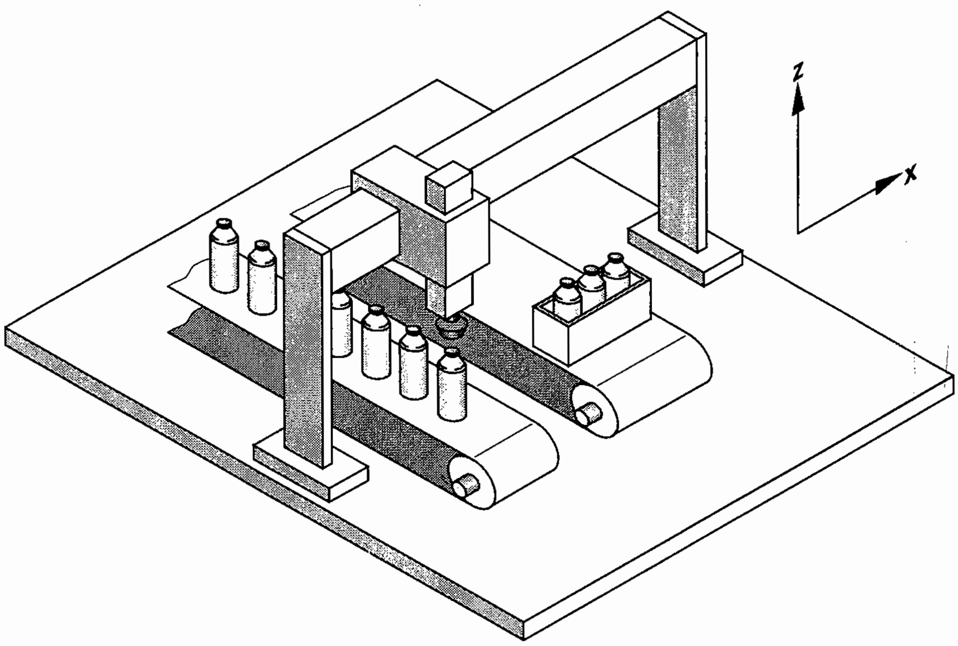


Fig. B3.5: Two axis handling device

3.3 Combination of three pneumatic NC axes

Many applications require handling devices which can move workpieces in all three axes, i.e. in the x, y and z directions. The area within which a gripper, e.g. the workpiece, can be moved forms the working area of a handling device.
Robots are handling devices with a minimum of three freely programmable axes.
Two handling devices or robots are shown in Figs. B3.6 and B3.7.

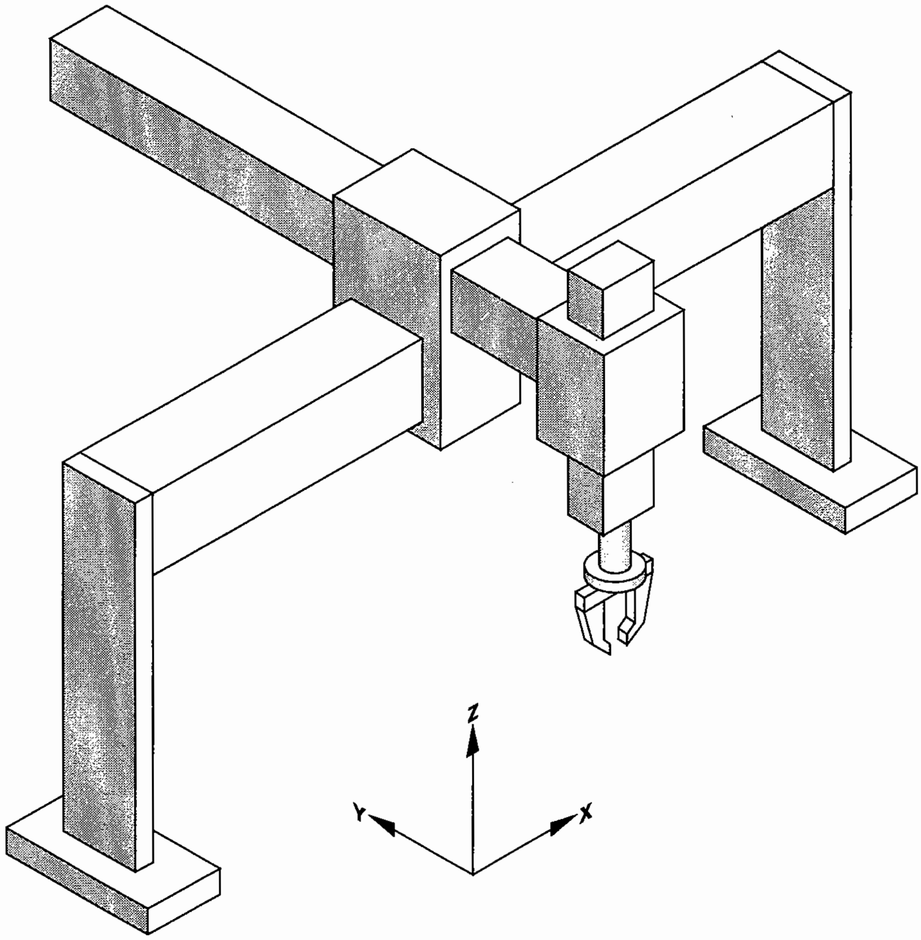


Fig. B3.6: Three axis handling device (cantilever design)

Cantilever

Fig. B3.6 shows a handling device in the form of a cantilever arm. An application of a device of this kind (placing workpieces on a pallet) was shown in Chapter B1.4.

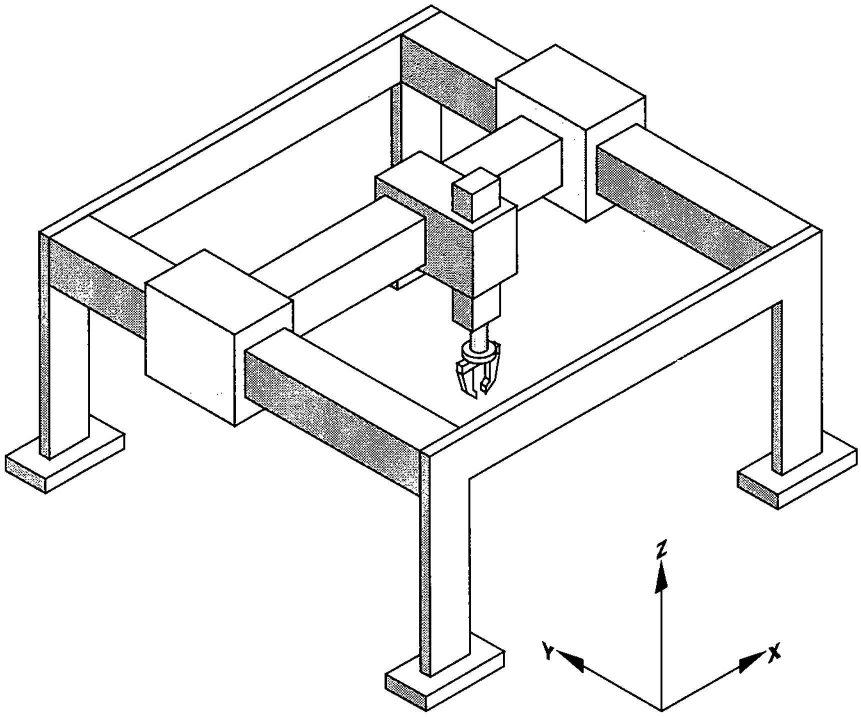


Fig. B3.7: Three axis handling unit (gantry design)

Gantry

The handling unit shown in Fig. B3.7 permits motions in the x, y and z directions. In contrast to the cantilever arm device, this device has a double linear guide in the y direction. The x axis is supported on both sides. The handling device is therefore very sturdy

This type of handling device is also referred to as a gantry, since the x and y axes span the working area like a gantry.

4. Dynamic control valves for pneumatic NC axes

4.1
Valve designs

A distinction is made in pneumatics between switching valves and dynamic control valves (Fig. B4.1).
Dynamic control valves are generally used for pneumatic NC axes. The following designs accordingly refer to this type of valve.

Pneumatic valves → Switching valves, Dynamic control valves

Fig. B4.1: Switching valves and dynamic control valves

Fig. B4.2 shows the Festo dynamic control valve MPYE 5-1/8, the type used in the present function package.

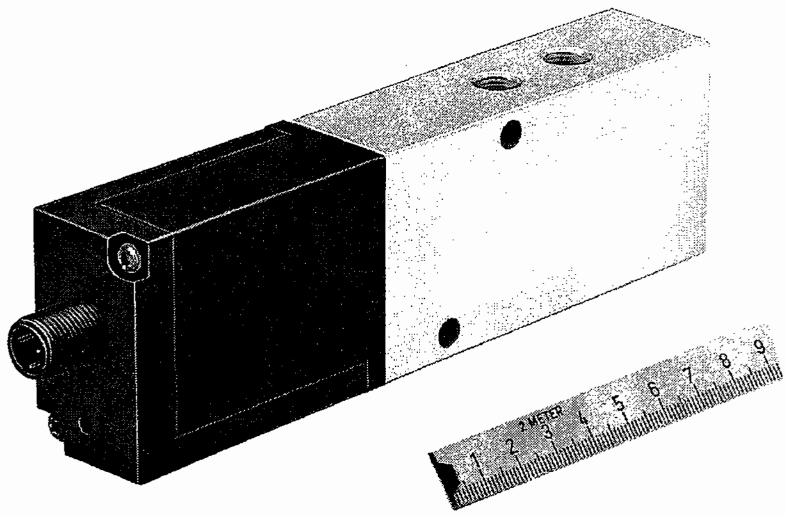
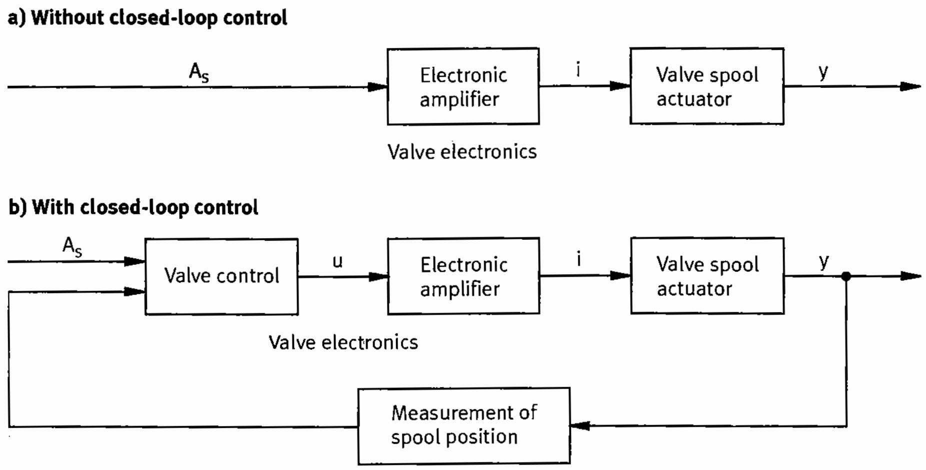


Fig. B4.2: Dynamic control valve MPYE 5-1/8

4.2 Mode of operation of a 5/3-way dynamic control valve

The illustration below shows the signal flow in a dynamic control valve.



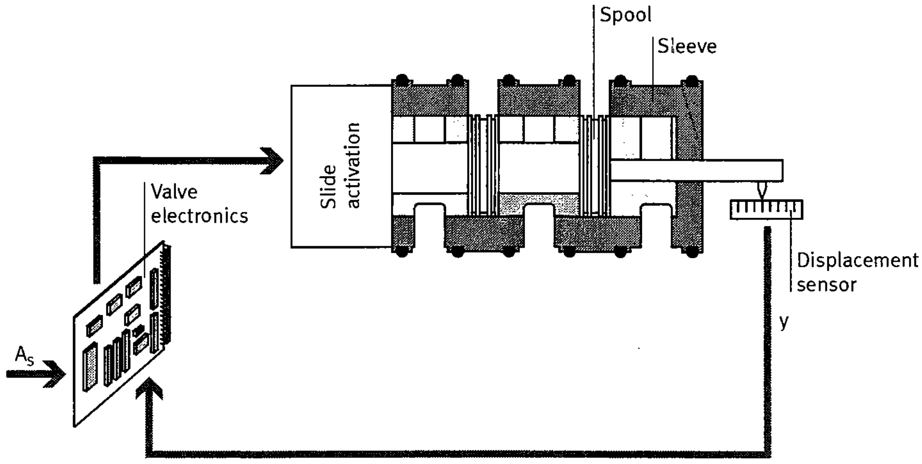
A_S = Valve actuating signal (control signal)
u = Controller output voltage
i = Valve actuating current
y = Valve spool position

Fig. B4.3: Signal flow in a dynamic control valve

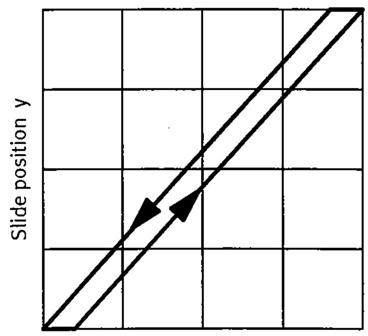
In the case of a valve without integrated closed-loop control (Fig. B4.3a) the control signal A_s acts directly on an electronic amplifier, which supplies current to the valve actuator. The valve spool can, for example, be actuated by a plunger, a torque motor or a proportional solenoid. The higher the actuating force, the greater the displacement of the spool.

Many dynamic control valves are equipped with an integrated closed-loop controller for the valve spool position (Fig. B4.3b). The position of the valve spool is continuously measured and compared with the input signal by means of an electronic controller. The electronic amplifier is triggered in this case not by the control signal directly but by the controller output signal.

a) Block diagram



b) Characteristic without closed-loop control



c) Characteristic with closed-loop control

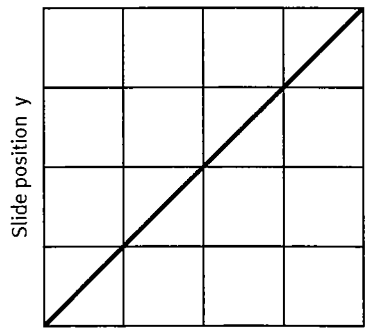


Fig. B4.4: Dynamic valve spool position as a function of the input signal

Fig. B4.4 shows the relation between control signal A_s and the valve spool position y.
The valve spool is affected by frictional and flow forces. In the case of a valve without closed-loop control, these have a relative strong influence on the valve slide position (Fig. B4.4b).
If the valve incorporates a closed-loop control, this compensates for the influence of friction and flow forces (Fig. B4.4c). Valves with closed-loop control are therefore used in all cases where maximum accuracy is required.

Figs. B4.5 and B4.6 show the valve spool position for various selected control signals.

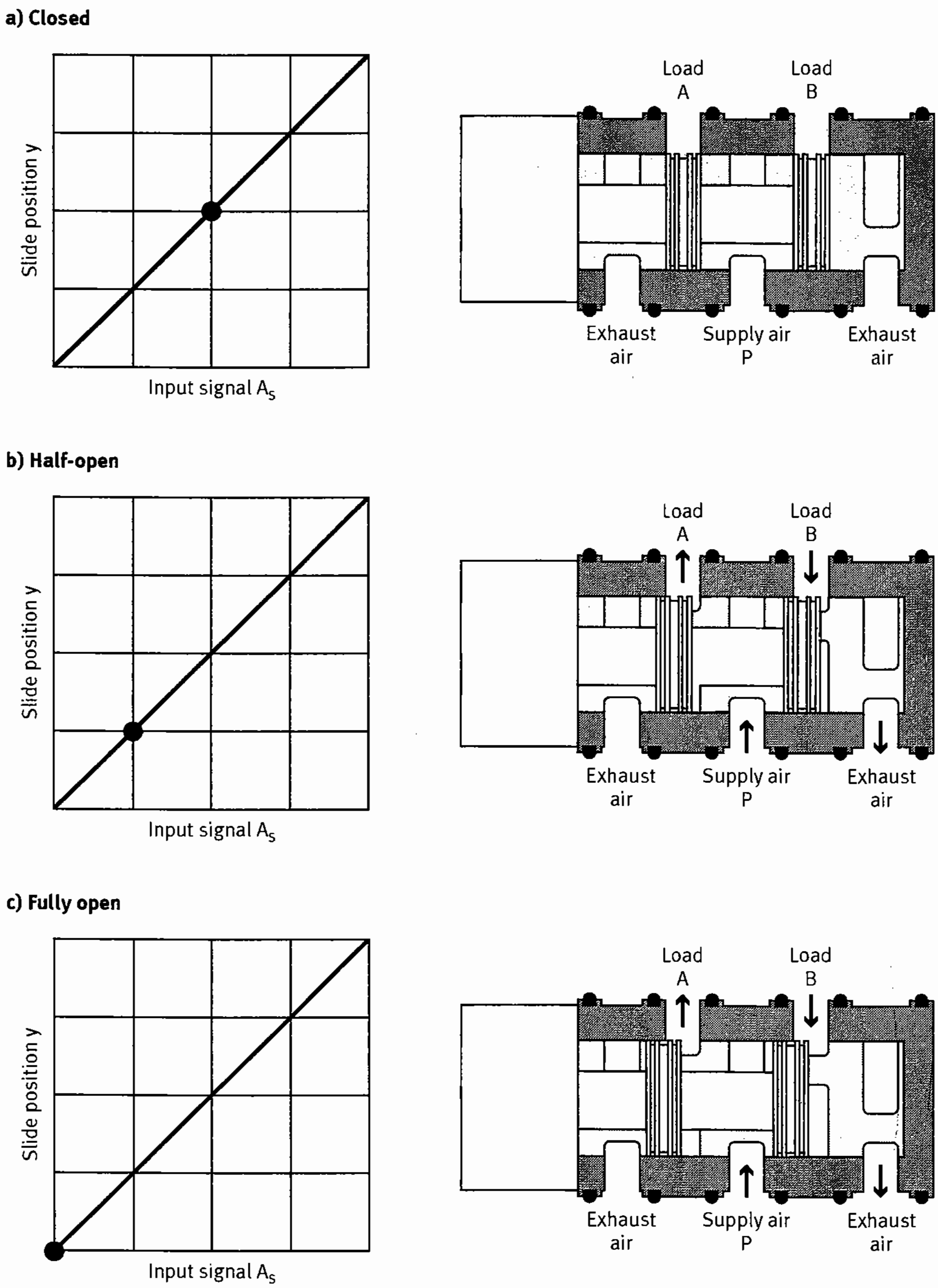


Fig. B4.5: Dynamic valve spool positions for selected control signals.

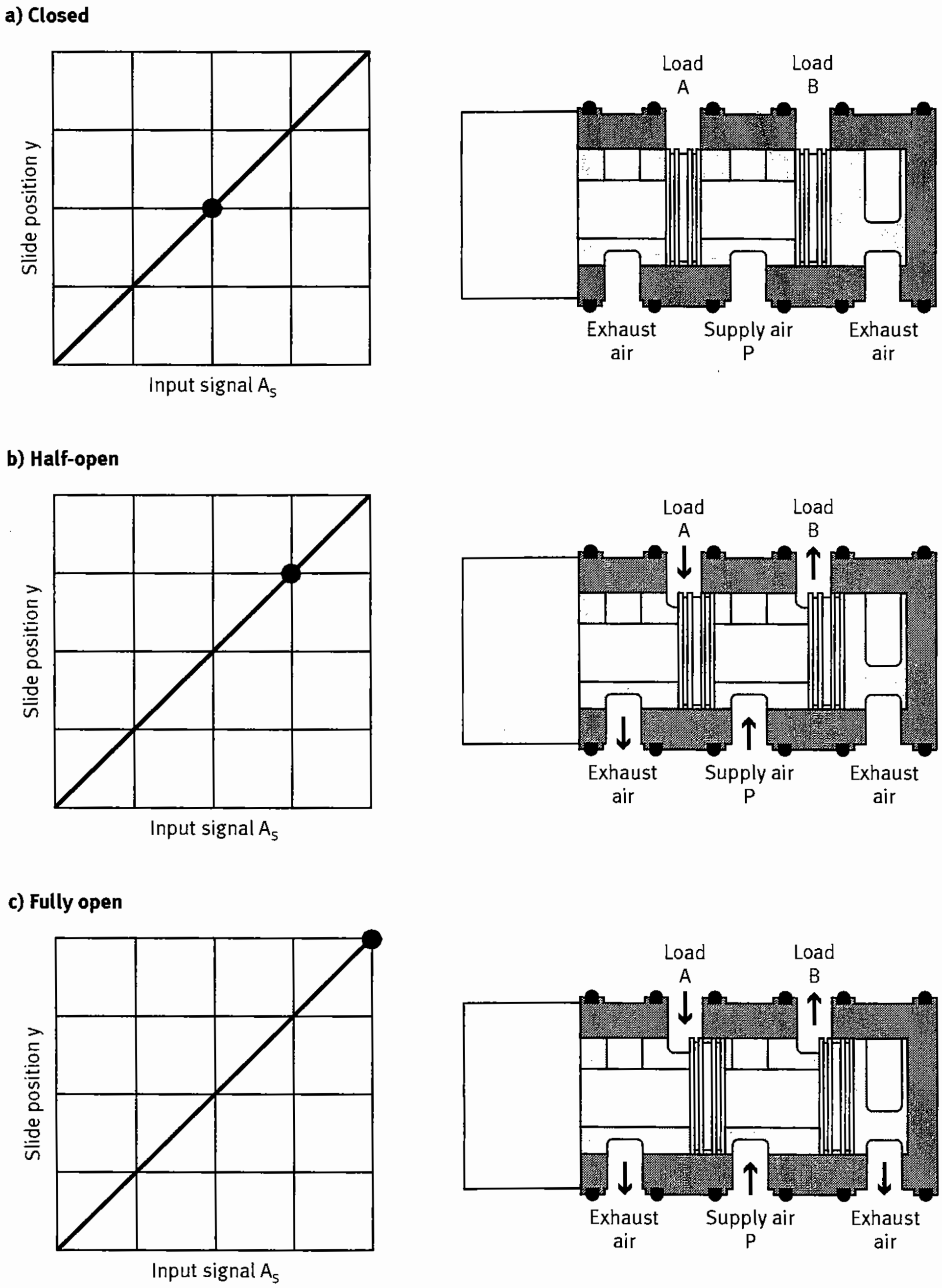


Fig. B4.6: Dynamic valve spool positions for selected control signals.

If a control signal is specified whose value lies in the mid-signal range, the valve spool will move to its mid-position (Fig. B4.5a). All control edges of the valve are closed. This means that no air can flow through the valve, apart from a very slight leakage rate.

If the actuating voltage is varied in the negative direction, the valve spool will move to the left (Figs. B4.5b and B4.5c). Compressed air flows from the supply port to working port A, while working port B is connected to the exhaust port of the valve.

A comparison of Fig. B4.5b and Fig. B4.5c shows that the flow cross-sections are increased when the valve spool is moved further to the left. The larger the flow cross-sections at the control edges, the higher the flow rate through the valve.

If the control signal is varied in the positive direction, the valve spool will move to the right (Fig. B4.6b and Fig. B4.6c). Working port A is connected to the exhaust port, while working port B is connected to the supply port. Once again: The principle is that the further the spool is moved away from its mid-position, the larger the flow cross-sections and thus the flow rate become.

Due to the continuous mode of operation of the valve, it is possible to obtain not only the spool positions shown in Figs. B4.5 and B4.6 but also any desired number of intermediate positions.

Benefits of a dynamic control valve in comparison with a switching valve

A 5/3-way dynamic control valve of the type described above facilitates the control of both very high and very low volumetric flow rates, depending on how wide the valve is opened. This type of valve thus combines the benefits of valves with very large nominal sizes and those of valves with very small nominal sizes.

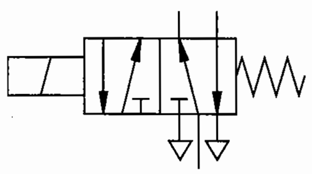
- At maximum valve opening (=large nominal size), very high piston speeds can be achieved.
- The valve, at minimum opening, permits very fine and precise modulation of the air flow, giving high precision for the positioning of a cylinder piston in a closed control loop. In this case, the valve behaves like a switching valve with a very small nominal size.

4.3 Variants of dynamic control valves and corresponding symbols

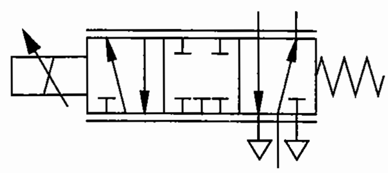
The dynamic control valve MPYE 5-1/8 described in Chapter 4.2 has three possible flow statuses, depending on the position of the spool:
- no flow in mid-position
- two opposite directions of flow, depending on the direction in which the valve spool is displaced (Figs. B4.5 and B4.6)

Since the valve has 5 ports and three positions, it is a 5/3-way dynamic control valve.

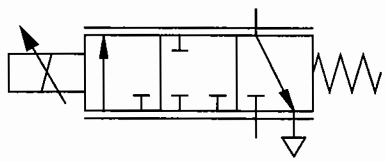
a) 5/2-way switching valve



b) 5/3-way dynamic control valve



c) 3/3-way dynamic control valvel



d) 5/3-way dynamic control valve MPYE 5-1/8

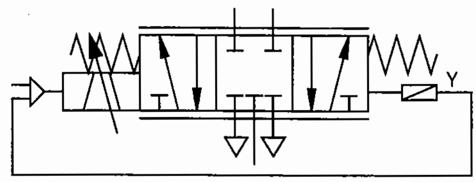


Fig. B4.7: Symbols for switching and dynamic control valves

The symbols for dynamic control valves can be distinguished from the symbols for switching valves by the double lines and the inclined arrows (Fig. B 4.7).
- Fig. B4.7a shows the symbol for a 5/2-way switching valve.
- Fig. B4.7b shows the symbol for a 5/3-way dynamic valve. The valve spool is actuated in this case directly by a porportional solenoid, while the return force is produced by a spring.
- Fig. B4.7c shows the symbol for a 3/3-way dynamic control valve (valve actuation, return: same as in Fig. B 4.7b).
- Fig. B4.7d shows the symbol for dynamic control valve MPYE 5-1/8. The valve spool is position-controlled. The spool is actuated by an electrical linear drive which can exert force on the valve spool in pulling and pushing directions.

3/3-way and 5/3-way dynamic control valves

A servo-pneumatic drive can be either actuated by two 3/3-way dynamic control valves or by one 5/3-way dynamic control valve (Fig. B4.8).
Accuracy and dynamics of the drive are virtually identical with both variants.

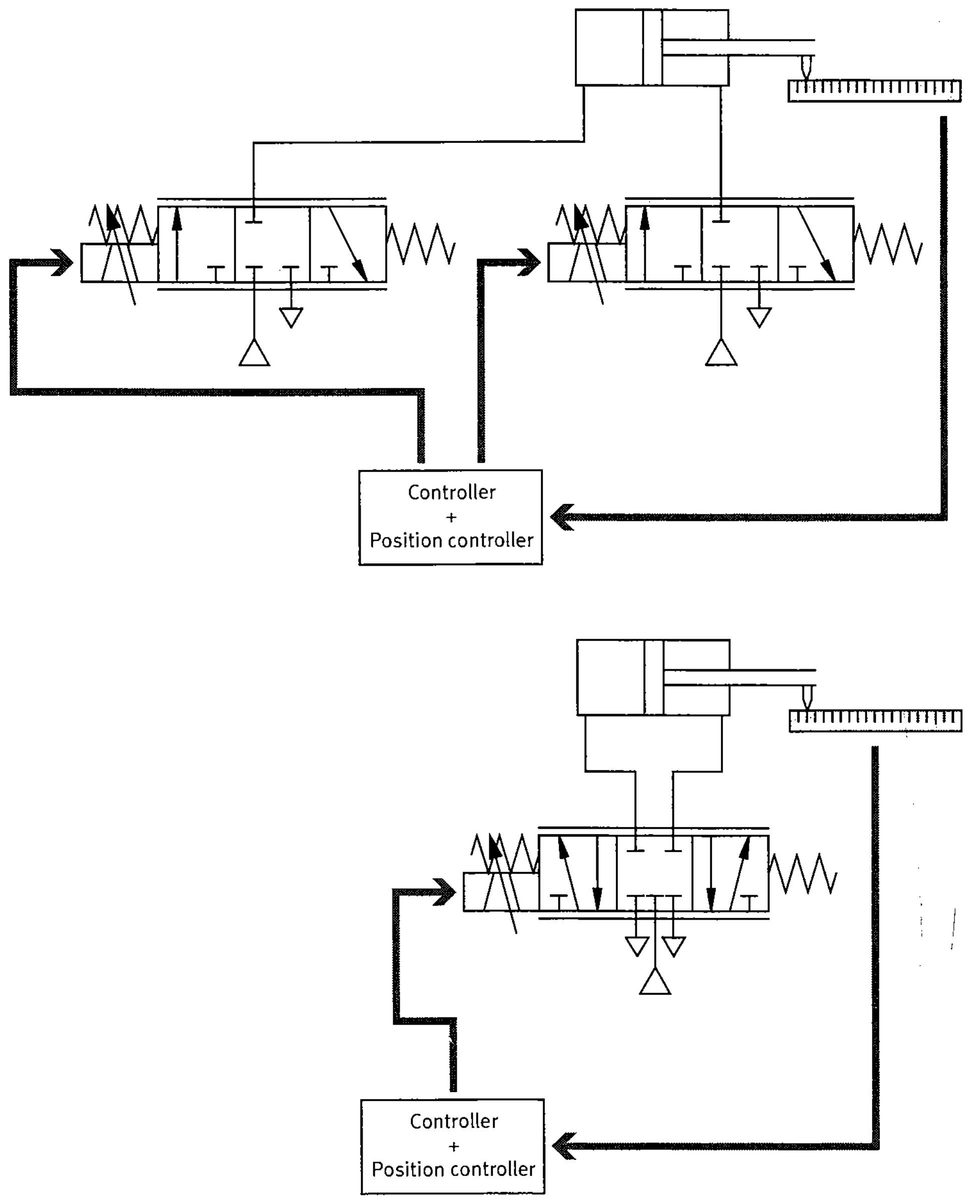


Fig. B4.8: Valve variants for servo-pneumatic cylinder drives

Both types of circuit are used in practice. A 5/3-way valve is used in the present function package. This solution, with the same performance data, is overall more economical.

Proportional and servo valves

In the case of dynamic control valves, a distinction is made in pneumatics, just as in hydraulics, between proportional and servo valves. Some important criteria for distinguishing these two classes of valves are listed in the table below.

	Proportional valves	**Servo valves**
Dynamics	low	high
Sturdyness	high	low
Accuracy	low	high
Actuation	direct	piloted
Power amplification	low	high
Price	low	high

Table B4.1: Characteristics of proportional and servo valves

A dynamic control valve will frequently exhibit the properties of both a proportional and a servo valve. In this case, it is up to the manufacturer concerned whether he classifies his valve as a proportional valve or a servo valve.

Festo proportional valve MPYE 5-1/8

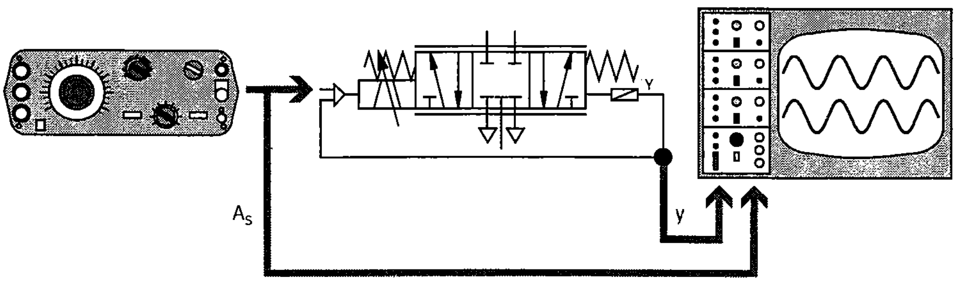
The valve MPYE 5-1/8 used in function package 3120/3121 has the following characteristics:
- simple, sturdy and economical design (characteristics of a proportional valve)
- high dynamics, high positioning accuracy (characteristics of a servo valve)

It cannot therefore be assigned unambiguously to one of the two categories of valves. Within the Festo product range, the valve is described as a proportional valve, due to the fact that the spool is directly activated.

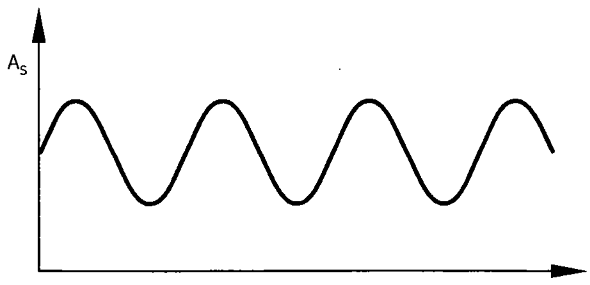
4.4 Characteristics of dynamic control valves

In order to obtain a high degree of control with a servo-pneumatic positioning drive, the valve spool position must follow the control signal not only as accurately as possible but also as quickly as possible. The limiting frequency is generally specified as an indication of the dynamic characteristics of a valve.

a) Test



b) Input signal



c) Spool position

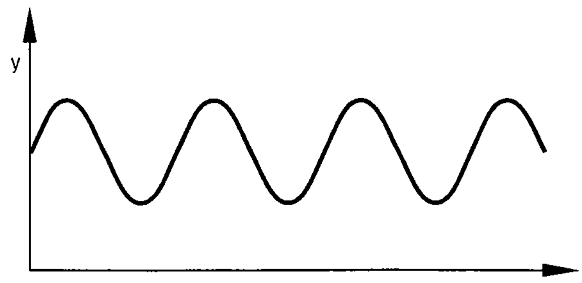


Fig. B4.9: Measurement of transmission characteristics of a dynamic valve

Measurement of valve dynamic characteristics

In order to measure the limiting frequency, the valves are actuated by a sinusoidal signal (Fig. B4.9). The position of the valve spool is also measured by means of a sensor. The valve spool oscillates at the same frequency as the control signal (Figs. 4.9b and B4.9c).

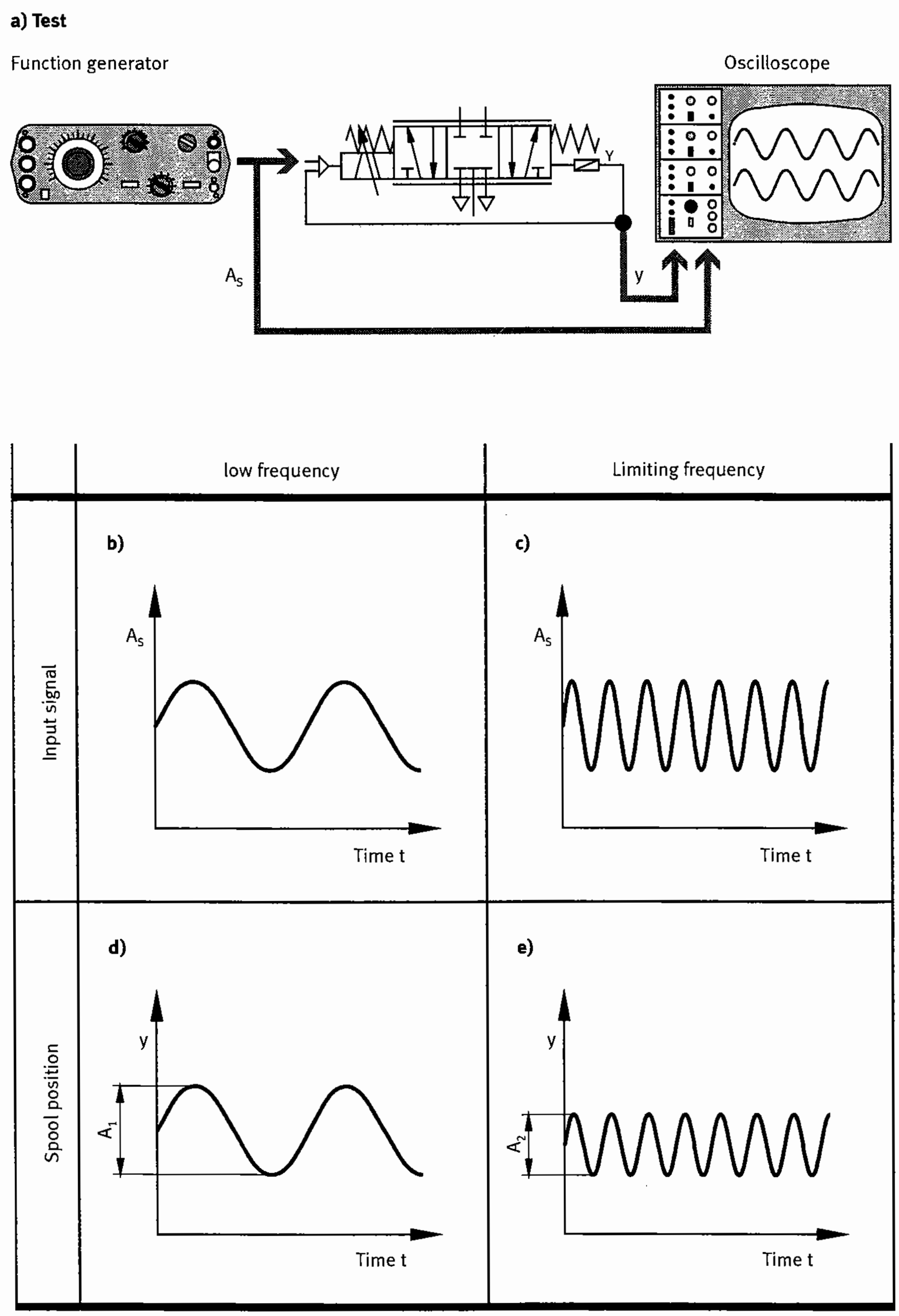


Fig. B4.10: Measurement of limiting frequency of a dynamic valve

If the actuating frequency is increased while maintaining the actuating amplitude, the frequency at which the valve spool oscillates also increases (Fig. B4.10). At very high actuating frequency the amplitude of the valve oscillation decreases, even though the actuating amplitude remains the same. The valve spool can no longer follow the control signal.

The limiting frequency is the frequency at which the amplitude of the valve oscillation has dropped to 70.7% of the initial value. Figs. B4.10c and B4.10e illustrate the actuation and limiting frequency. The amplitude, A2 in Fig. B4.10e, approximates to 70.7% of the amplitude A1 in Fig. B4.10d.

Data sheets also describe the limiting frequency as -3dB frequency. The term „-3dB“ (minus three decibel) means that the amplitude has dropped to 70.7% of the initial value. As an example you can refer to the characteristic curve for the MPYE valve in the corresponding data sheet. Limiting frequency is approx. 80Hz (80 oscillations per second).

4.5 Performance data for proportional valve Festo MPYE 5-1/8

Table B4.2 summarises the characteristic data of Festo valve Type MPYE 5-1/8 used in PneuPos.

Valve type	5/3-way dynamic control valve with position-controlled valve spool
Housing	
Valve ports	1/8"
Permissible supply pressure	0 - 8 bar
Port pattern	compatible with Festo switching valve JMFH, mountable on valve manifold PRS 1/8"
Electronics	
Configuration	Electronics fully integrated into valve
Supply voltage	24 V
Actuating signal	0 - 10 V
Performance data	
Standard nominal flow rate via 1 control edge (6 bar against 5 bar)	700 l/min
Range of inversion	less than 1%
Limting frequency at 100% signal amplitude	80 Hz

Table B4.2: Performance data of Festo proportional valve Type MPYE 5-1/8

5. Open-loop control of pneumatic NC axes

5.1 Functions of an open-loop control system

The open-loop control system for an NC axis has to perform the following functions (Fig. B5.1):

- Coordination of the motions of the NC axis to the production installation. This requires the functions of a programmable logic controller.
- Setpoint values must be specified for the positioning of the NC axis. This function is provided by a numerical control.

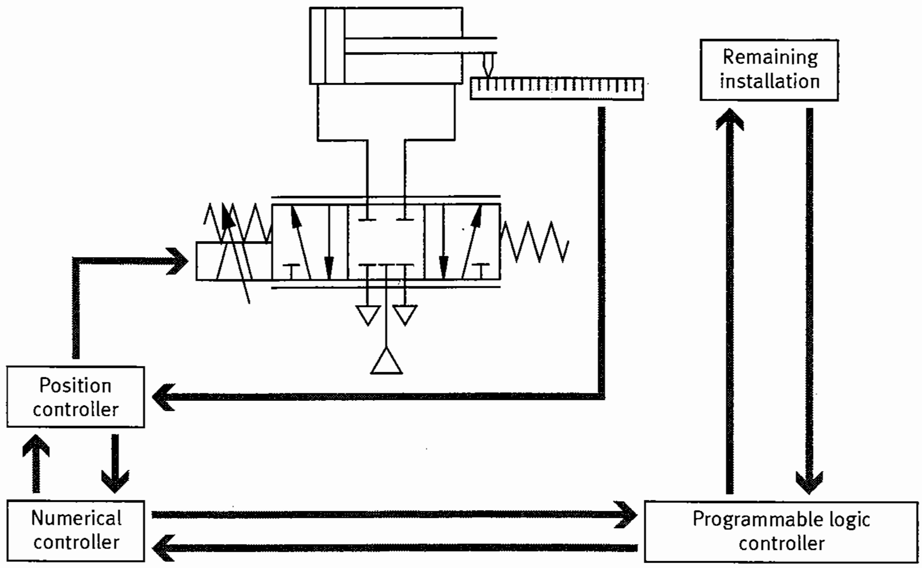


Fig. B5.1: Open-loop control for an NC axis

The functions of the control system can be illustrated by a package sorting machine (Fig. B3.3):

- The binary sensor signals are evaluated to determine the size of the package arriving on the conveyor belt. The binary signals are processed by a PLC for this purpose.
- The setpoint position value for the pneumatic NC axis is specified as a function of these signals. In the case of a medium-sized package, for example, the centre position will be approached, to enable the package to be transferred via the chute to the second conveyor belt.

5.2 Components of a control system

The open-loop control system for an NC axis consists of

- Control system hardware
- Control system software

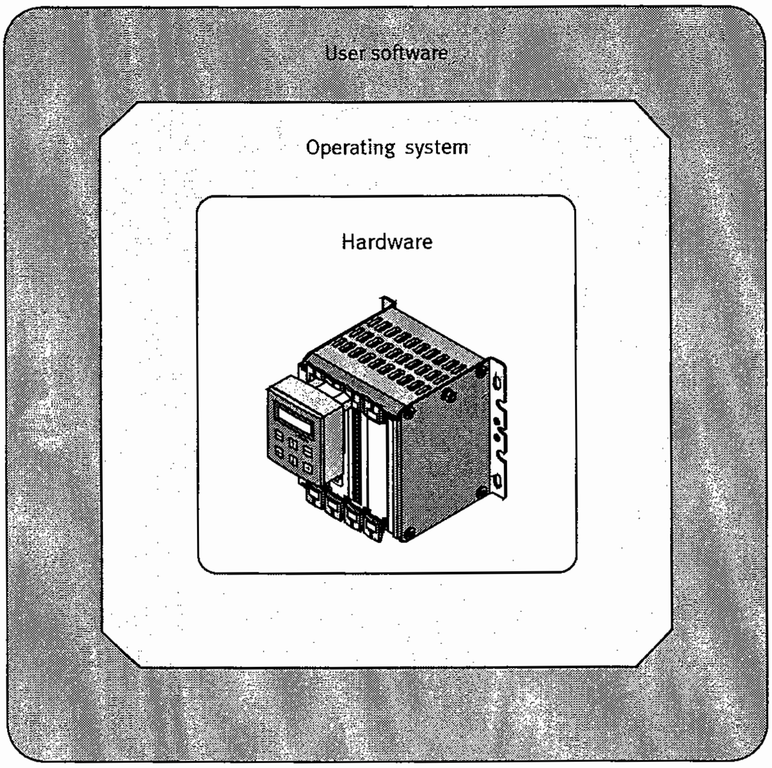


Fig. B5.2: Control system hardware and software

A distinction is made between the system hardware (operating system) and user software (Fig. B5.2).

- The operating system provides the user with a user and programming interface. The operating system is a permanent part of the controller and cannot be modified by the user. The operating system is stored in such a way that it is not erased when the controller is switched off or the power supply fails.
- The user program defines the motion of an NC axis and the coordination of this with the rest of the installation. The program must be generated by the user of the numerical controller (see Chapter B5.6). The user program is stored in a RAM (Random Access Memory = reading and writing memory).

NC axis controller
Festo SPC 200

Fig. B5.3 shows the NC axis controller Festo SPC 200. The axis controller combines the following functions:

- a numerical control for one or numerous pneumatic NC axes
- a programmable logic controller with binary inputs and outputs
- a closed-loop position control for one or numerous pneumatic NC axes (see Chapter B6)

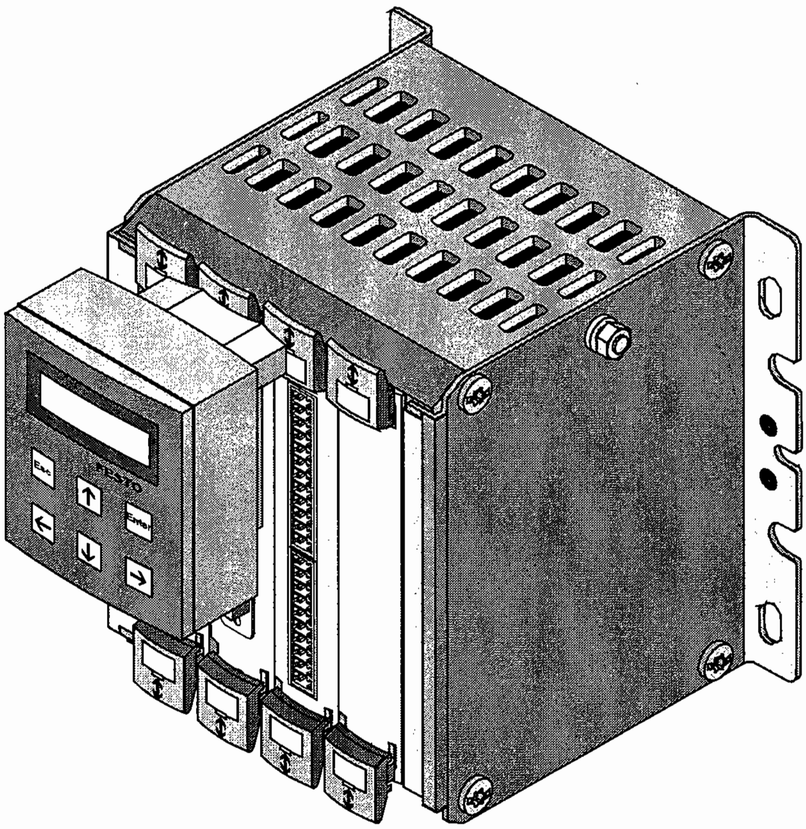


Fig. B5.3: Axis controller Festo SPC 200

The number of inputs and outputs and the set of commands for the integrated PLC of the SPC 200 are sufficient to control simple installations. Only one SPC 200 is therefore required to control the package-sorting installation (Fig. B5.4). There is no need for an additional PLC.

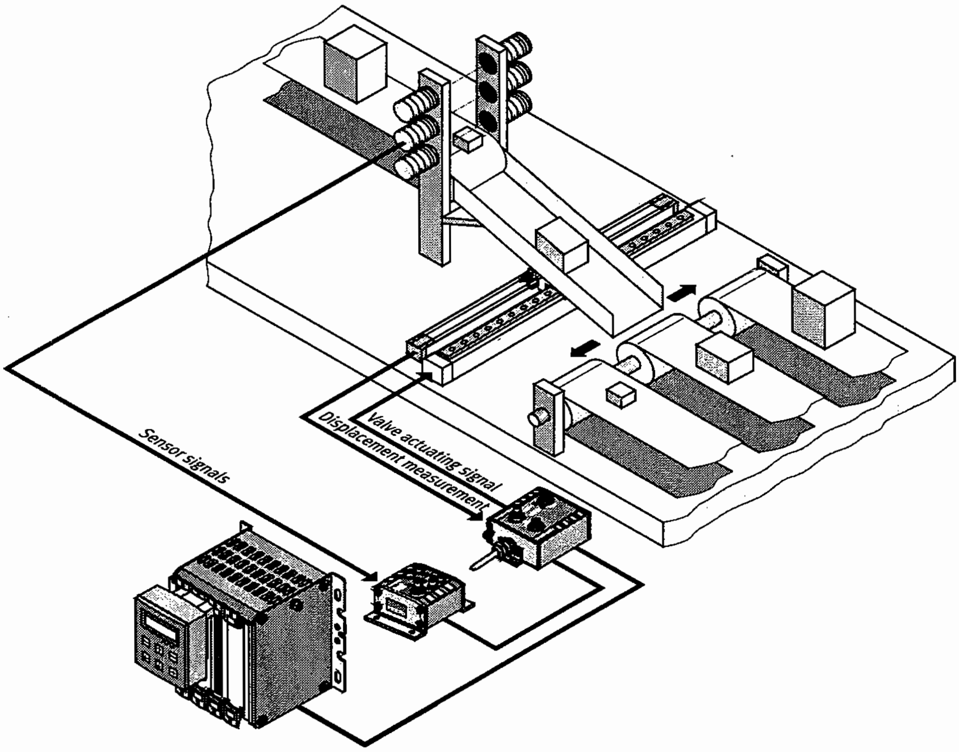


Fig. B5.4: Controlling a package sorting installation using the SPC 200

Frequently the pneumatic NC axis will be part of a very complex installation or a complete production line. In this case the overall installation will be monitored and controlled by a separate PLC. The programmable logic controller transmits a binary signal to the SPC 200 in order to trigger a motion of the NC axis. As soon as the new position has been reached, the SPC 200 transmits an acknowledgement binary signal for the new position to the PLC.

5.3 Configuration of a multiple axis control

For many applications in automation technology, it is necessary to achieve coordinated motions of several numerically controlled axes. Examples are as follows:

- Palletising with a handling device (Fig. B1.4)
- Welding of automobile bodywork by means of a robot
- Machining of valve bodies by means of an NC milling machine.

Control of robots and machine tools

In case of robots and NC machine tools, a single numerical controller is generally used to coordinate the motions of all the axes. Numerical controllers for robots and machine tools are therefore designed for 3 to 6 axes. A suitable control configuration is illustrated in Fig. B5.5.

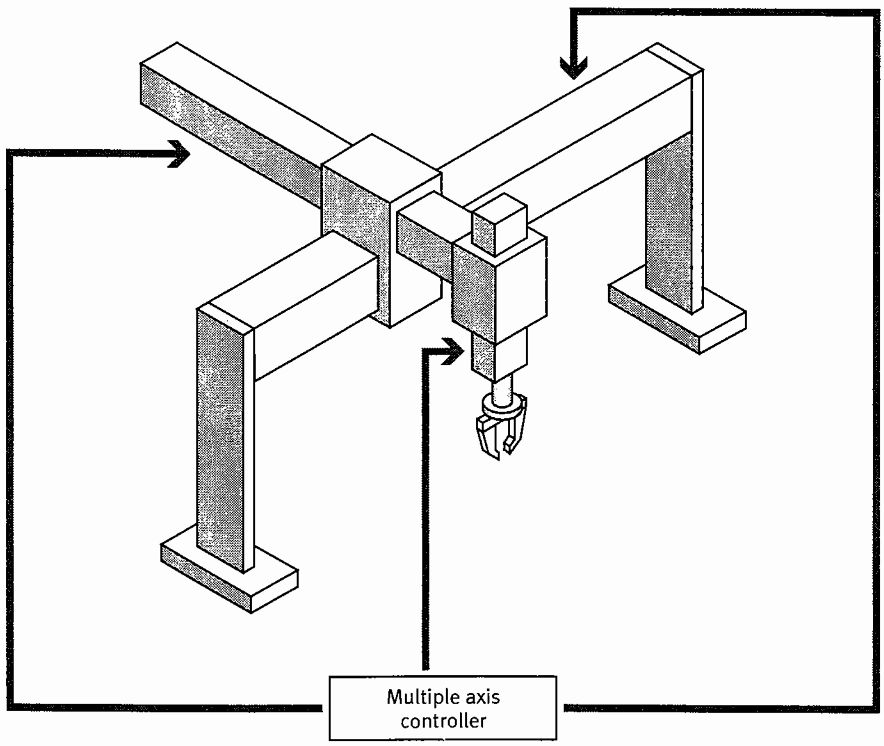


Fig. B5.5: Multiple axis controller for machine tools and robots

Open-loop control of NC axes (handling technology)

Controllers for NC axes in handling systems must fulfil the following requirements:

- Controllers for single axes must be as inexpensive as possible.
- It must be possible to operate multi-axis devices with a single controller. It should be possible for users to control all the NC axes with a single motion program, without the need to program each axis individually.
- It should be possible to use the same method to program single and multi-axis applications.

In order to allow all these requirements to be met, controllers for NC axes should preferably be of modular design. Fig. B5.6 shows in schematic form a controller configuration for a handling system with two pneumatic NC axes. This uses the same controller as was used with the single NC axis in Fig. B 5.4. Each of the two axes is connected to the SPC 200 controller via an axis interface.

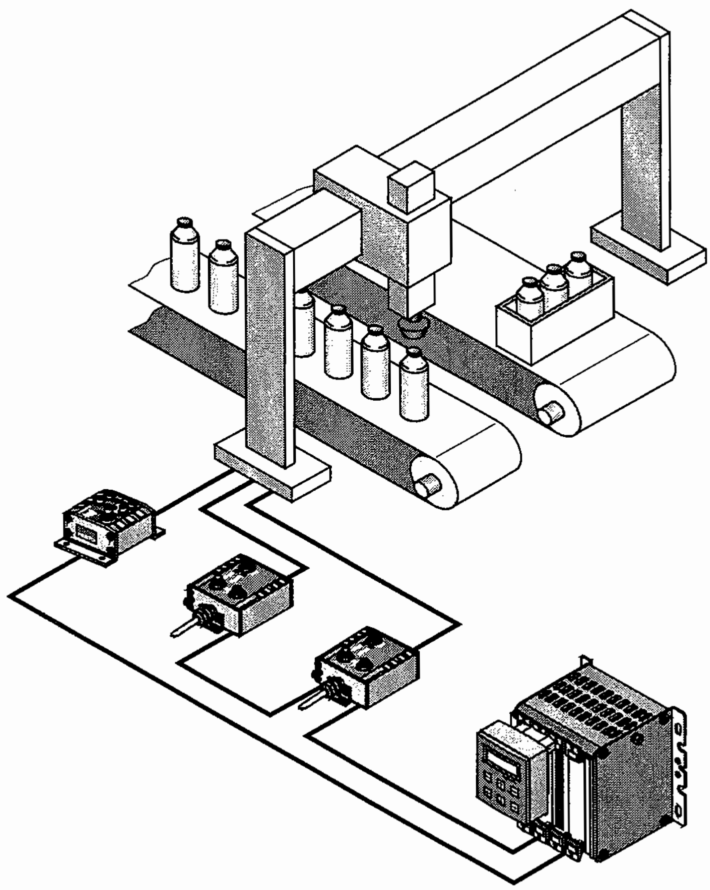


Fig. B5.6: Controller for a system with two pneumatic NC axes

5.4 User interface of a numerical controller

The user interface of a numerical controller permits the operator to input data and commands into the controller and read information out.
The interface has three major functions:

- Parameterisation (adaption of the controller to the NC axis, Chapter. B5.5)
- Programming, (input of motion sequence for the NC axis, Chapter B5.6)
- Diagnostics (error detection, optimisation of the motion characteristics of the NC axis, Chapter. B5.7)

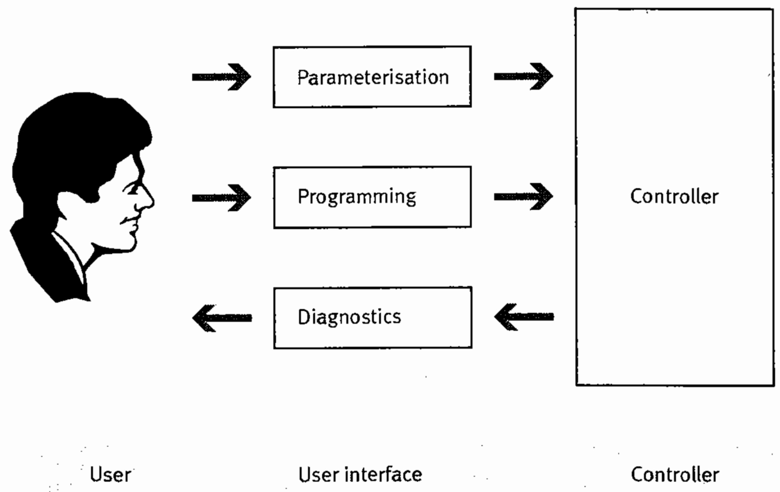


Fig. B5.7: User interface functions

The following devices can be used as user interface of a numerical controller (Fig. B5.8):

- a control panel integrated into the front of the controller
- a terminal
- a personal computer
- a hand-held device

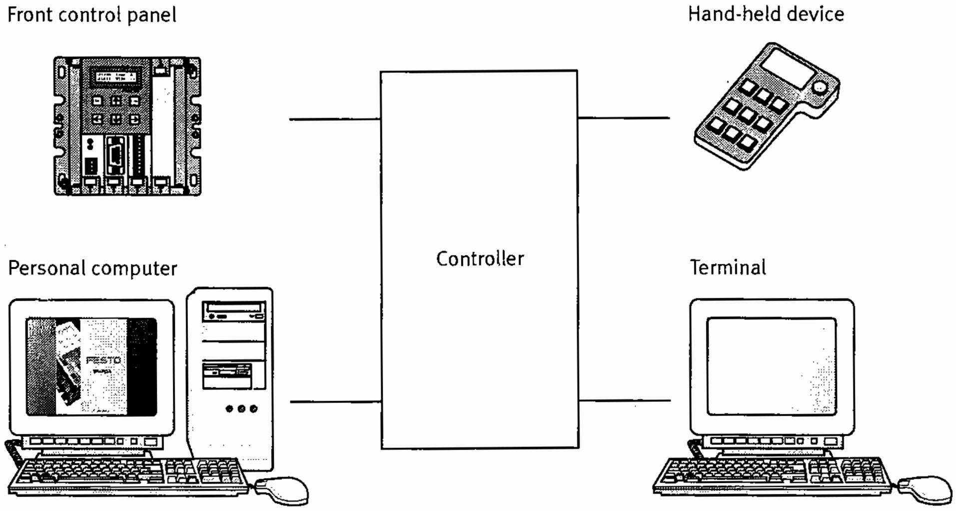


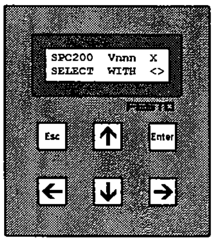
Fig. B5.8: User interface devices for a numerical controller

Example of a user interface

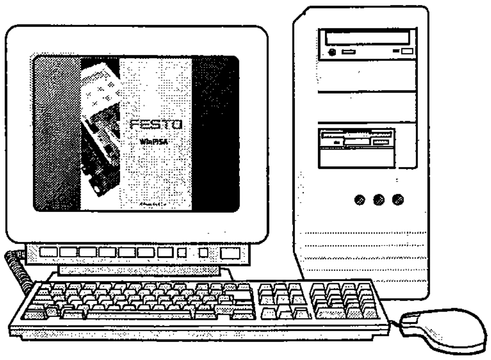
The Festo SPC 200 numerical controller can be operated via the following interfaces (Fig. B5.9):

- the front control panel of the axis controller
- a personal computer with WinPISA software (programming and commissioning of servo-pneumatic drives).

Front control panel



Personal computer



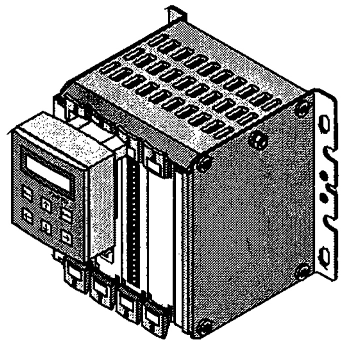


Fig. B5.9: User interfaces for control of pneumatic NC axes

The integrated control panel permits data to be entered and read without the need of additional devices. A PC and WinPISA software provide a simpler and more convenient method of operating the controller than the integrated front panel.

5.5 Parameterisation of a numerical controller

Numerical controllers, such as the SPC 200, can be used for different types of NC axes without modification to their hardware.

In order to match the controller to a particular NC axis, the characteristic data for this axis must be entered via an interface (parameterisation of the controller). Parameterisation needs to be carried out once only during the commissioning of an NC axis.

The following characteristic data are generally required for parameterisation:

- Drive type and characteristic data
- Length of axis
- Length and type of displacement encoder
- Maximum speed and acceleration of the axis
- Closed-loop coefficients.

In WinPISA, parameterisation is divided into different menus. Fig. B5.10 shows the menu for the input of drive data.

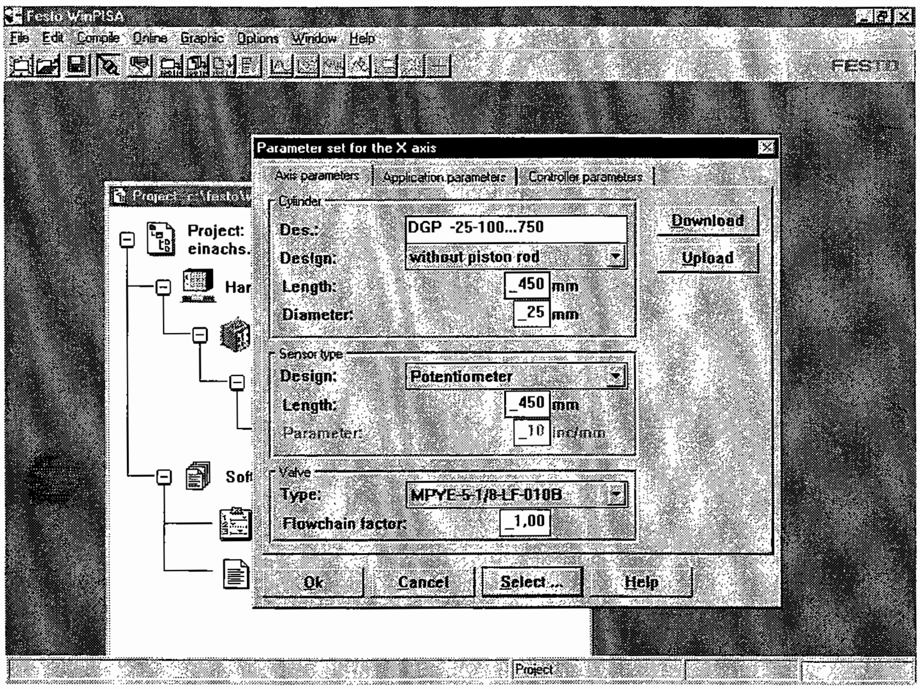


Fig. B5.10: Parameterisation of a pneumatic NC axis by means of WinPISA

5.6 Programming of a numerical controller

The motion sequence for a numerically controlled axis consists of various positions which the NC axis is to approach in succession. Frequently, traversing speed and acceleration are also determined by the user program.

Programming languages for numerical controllers

Various programming languages have been developed for the programming of numerically controlled axes. They permit users to program the desired motions of NC axes with relatively little effort.

The programming language as per DIN 66025 was originally developed for numerically controlled machine tools. It is also used in handling technology, e.g. for servo-pneumatic axes in function package PneuPos.

Flow chart

The flow chart (Fig. B5.11) shows the procedure for the programming of a numerical controller in graphic form.

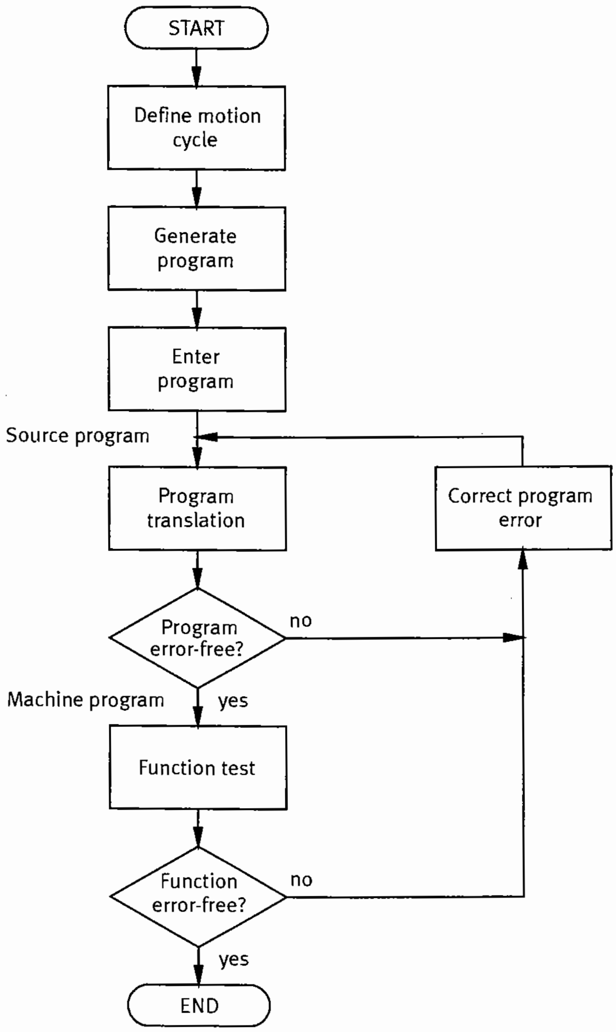


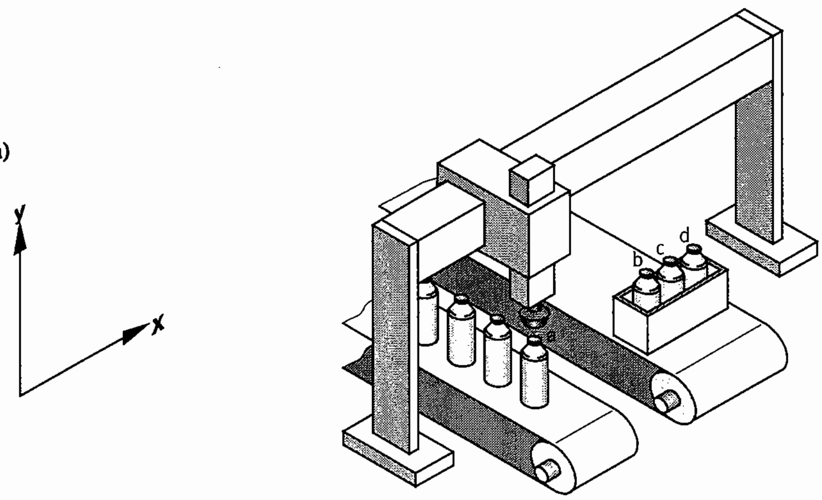
Fig. B5.11: Procedure for the programming of an NC controller

Example of an NC program

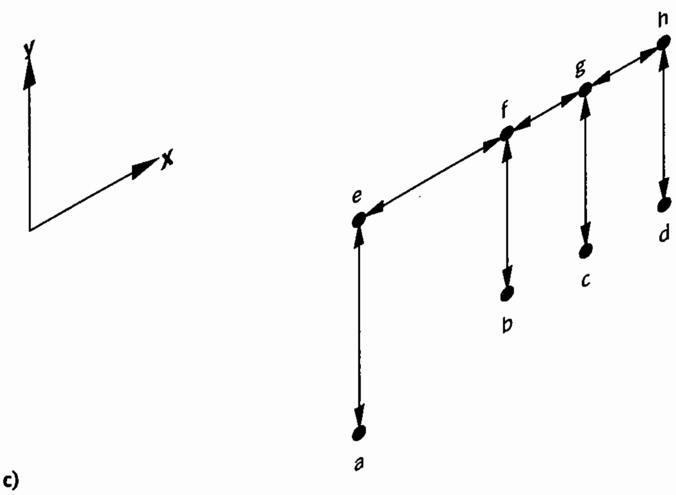
The procedure for the programming of NC axes will be illustrated by means of an example.

Fig. B5.12a shows an installation used to sort bottles into a carton. The installation has two pneumatic NC axes. The first axis moves horizontally (x direction), while the second axis moves vertically (y direction). The bottles are picked up in position a and sorted into the carton in positions b, c and d (Fig. B5.12a).

a)



b)



c)

	x/mm	y/mm
a	100	100
b	250	150
c	350	150
d	450	150

	x/mm	y/mm
e	100	350
f	250	350
g	350	350
h	450	350

Fig. B5.12: Two-axis packaging device and pertaining position table

Determining the motion sequence

This operation is divided into individual motions. In order to transport a bottle from position a to position b, it is
- picked up in position a
- lifted into position e
- transported horizontally to position f
- lowered vertically into the packaging (position b).

Program generation

Generally the coordinates of a position are entered by the user via the Teach-In method. This operation comprises the following steps:
- The two NC axes are moved by means of the WinPISA controller panel until the desired position has been reached.
- The allocated positions of the two axes are entered in the position list.

This operation will be carried out for all positions a to h.
Fig. B5.13 shows the position table for the packaging device in Fig. B5.12 a.

The user must also generate the motion program. Fig. B5.13 shows the program for the packaging machine in Fig. B5.12. Apart from the actual motion commands, the program also includes commands for the triggering of the gripper and the conveyor belts.

Syntax check

Following the input, a check is made to see that the user has entered only commands that are permissible within the programming language in question (syntax check).

Translation of the program into machine language

As soon as the user has corrected any syntax errors, a command sequence for the controller in machine language is generated from the user program. This machine program is then loaded into the user memory of the controller.

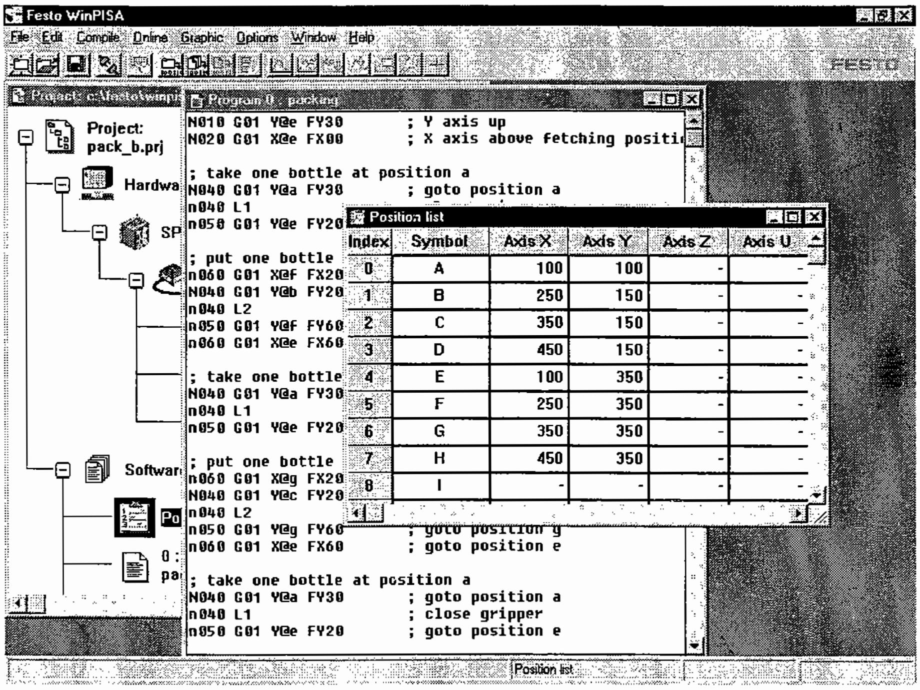


Fig. B5.13: Motion program and position table of packaging device

Testing the program

The completed program can now be tested with the installation. If errors are detected, the user program must be modified. All steps following must be repeated until the entire installation runs free of errors.

5.7 Diagnostics with a numerical controller

While it is necessary to enter data into the controller during parameterisation and programming of an NC axis, data must be read out of the controller for the purpose of diagnostics.(Fig. B5.8).

Diagnostic functions of a numerical controller are used to

- optimise the motion characteristics of a numerically controlled axis
- reduce the time required for commissioning of the axis
- in case of faults to determine the cause of failure as quickly as possible in order to minimise downtime.

Example of diagnostic functions

The SPC 200 controller used in the present function package provides the following functions:

- display of error messages (e.g. if the target position has not been reached over a lengthy period)
- display of additional data if required by the user (e.g. controller settings)
- graphic representation of motion characteristics

To provide a graphical display of the relevant motion characteristics, a personal computer loaded with WinPISA software is connected to the controller. Curves for position, speed, acceleration and the manipulated variable as a function of time are recorded and displayed on the computer screen (see Chapter 6). It is also possible to display various binary signals. This graphical display allows the behaviour of an NC axis to be monitored and optimised easily (Fig. B5.14).

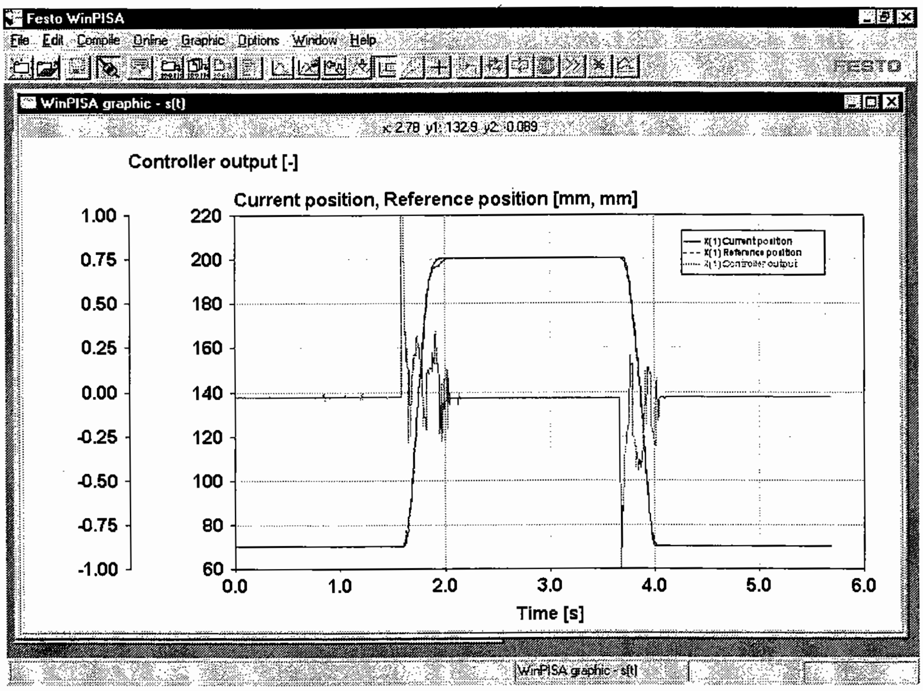


Fig. B5.14: Motion sequence for positioning of a servo-pneumatic NC axis

6. Closed-loop control of pneumatic NC axes

6.1
Closed-loop controllers for NC axes as appropriate to drive technology

Various types of drives can be used for numerically controlled axes (see Chapter. B1):

- servo-pneumatic drives
- electrical stepper motors
- electrical servo motors
- servo-hydraulic drives

Different drive variants require different closed-loop controllers.

- Stepper motor drives do not generally require a closed-loop controller.
- Electrical servo motors as well as servo-hydraulic and servo-pneumatic drives require closed-loop control. They differ in the types of sensors used and the configuration of the controller used (Table B6.1).

Drive	Sensor	Position control	Most common control method
Stepper motor	–	seldom	–
Electrical servo motor	Tachometer + displacement encoder	Yes	Cascade closed loop control
Hydraulic positioning drive	Displacement encoder	Yes	Single or triple closed loop control

Table B6.1: Control and sensors used for numerically controlled drives

In the following, only the configuration of a closed-loop position controller for a pneumatic NC axis will be described.

6.2
Closed control loop components of a servo-pneumatic positioning drive

Fig. B6.1 shows the closed control loop of a servo-pneumatic positioning drive used in the present function package. The control loop comprises the following components.

- a position controller (integrated into the servo-controller SPC 200, see Chapter B5.2)
- a dynamic valve
- a drive cylinder
- a displacement encoder

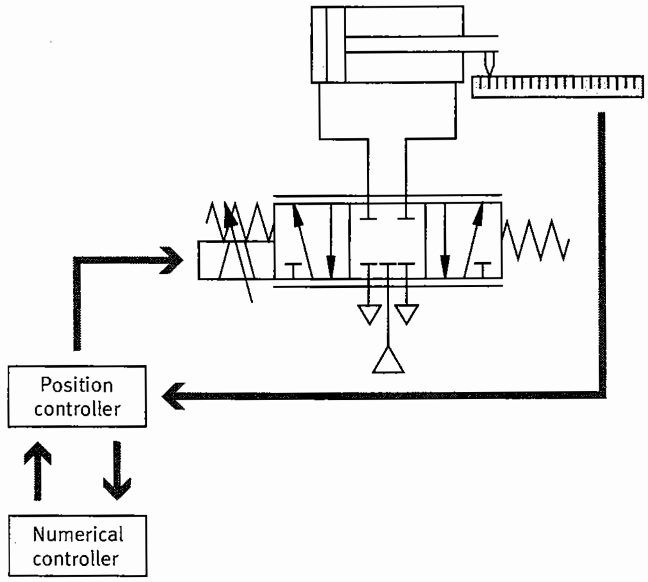


Fig. B6.1: Closed-loop control for a servo-pneumatic positioning drive

6.3 Structure of a position controller

The triple loop control structure is shown in Fig. B6.2. The two input signals to the closed-loop controller are:

- The setpoint position x_{setp} (specified by the numerical controller)
- The actual position value x_{act} (determined by the displacement measuring system).

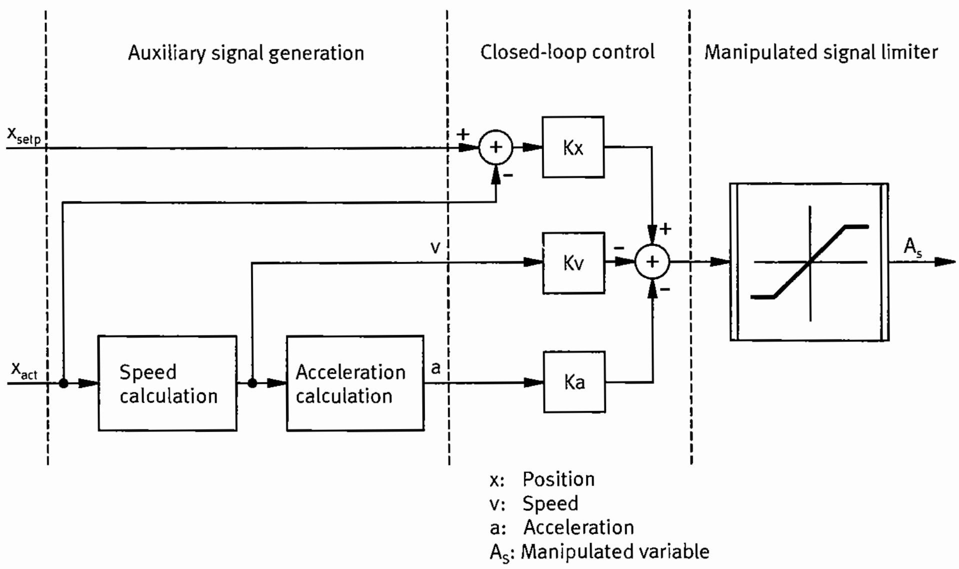


Fig. B6.2: Structure of a triple-loop position controller

In order to achieve good control accuracy and dynamic characteristics, speed and acceleration of the drive piston are evaluated in addition to the actual position. Both variables are calculated using the signal from the measuring system. This process is simpler and more economical than measurement with additional sensors.

Triple-loop position controller

Setpoint position and actual position, speed and acceleration values form the input signals to the position controller itself(Fig. B6.2). The controller is used to carry out the following operations.

- Calculation of position deviation (difference between setpoint position and actual position) and multiplication by the controller gain K_x
- Caclulation of the product of speed v and controller gain K_v
- Callculation of the product of acceleration a and controller gain K_a
- Summarisation of the three controller components

The cumulative signal is limited and is switched to the proportional valve in the form of control signal A_S .

Limiter circuit

The characteristic for the limiter circuit is illustrated in Fig. B6.3. A distinction is made between the following working ranges:

- If the signal at the input of the limiter circuit lies outside the adjustable range of the valve, the manipulated variable is limited at the output of the limiter to its maximum or minimum value. In this case, the valve is opened fully (working ranges 1 and 3 in Fig. B6.3).
- If the signal at the input of the limiter circuit lies within the adjustable range of the valve, the input signal of the limiter is fed straight through to the output. The limiter function is inoperative, the valve opening is proportional to the controller output signal (working range 2 in Fig. B6.3).

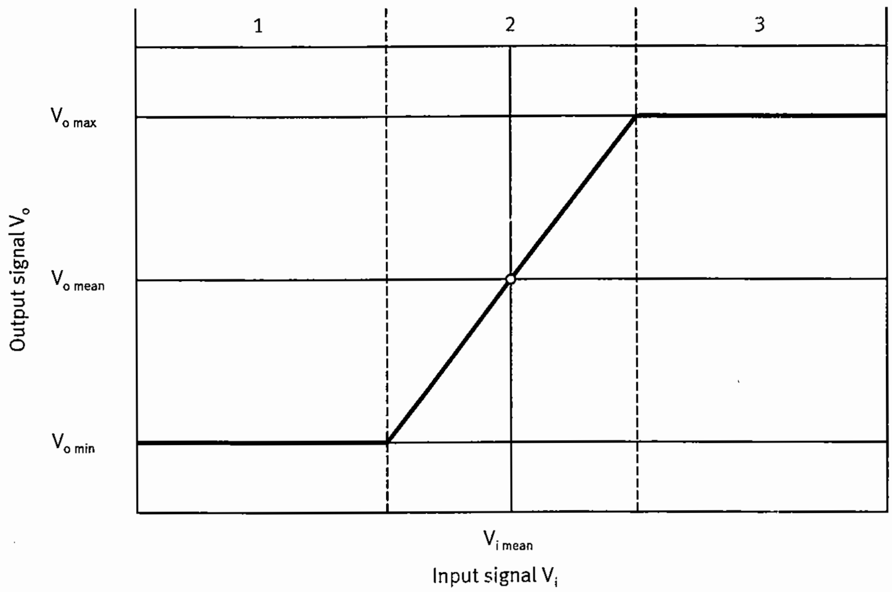


Fig. B6.3: Characteristic of a limiter circuit

Controller adaption

In order to ensure consistently good control characteristics even with changed parameters, such as fluctuations in supply pressure, the control characteristics are monitored continuously. If required the controller coefficients are re-adjusted automatically (controller adaption).

6.4 Benefits of digital closed-loop control

Positioning of servo-pneumatic drives is generally realised by digital means, that is to say via computer. In comparison with analogue closed-loop control, digital closed-loop control offers the following benefits:

- Higher control accuracy.
- Control accuracy is less influenced by temperature and long-time drift of electronic components than with analogue controllers.
- Less sensitivity to interference and noise.
- Additional functions, such as monitoring of control characteristics and controller adaption, can be provided simply, inexpensively and reliably.

6.5 Controller hardware

Fig. B6.4 illustrates the hardware structure of a digital closed-loop electronic controller

Hardware structure

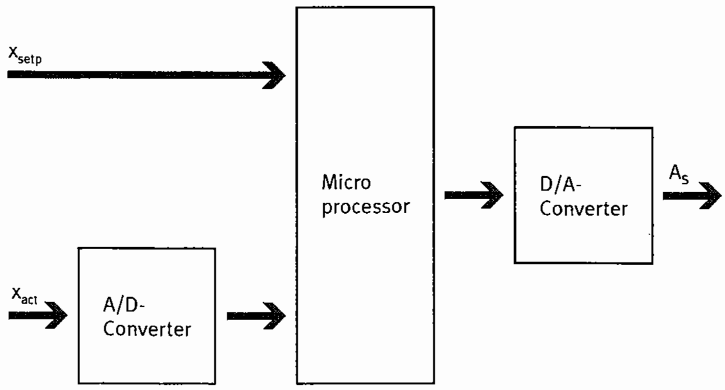


Fig. B6.4: Hardware structure for digital closed-loop electronic controller

The controller hardware comprises the following components:

- an analogue/digital converter as input interface
- a processor in which the control program runs
- a digital/analogue converter as an output interface

Controller input interface

If an analogue displacement measuring system (e.g. potentiometer) is used, the position value, present in this case as a voltage, must be converted into a numerical value via an analogue/digital converter (A/D converter). In case of a digital measuring system, the A/D converter is replaced by digital electronic evaluation circuitry.

The setpoint position is specified by the control program. It is therefore already available as a numerical value and does not need to be converted.

Processor

Input signals are further processed by the processor. The result of these operations is the manipulated variable.

Controller output interface

The manipulated variable is converted into an electrical voltage by means of digital/analogue converters (D/A converters). The proportional valve is actuated by this voltage.

Micro-controller

Digital controllers are generally realised through micro-controllers. These are micro-processors with additional integrated functions such as interfaces, memories and converters. By combining all major modules in a single integrated circuit, it is possible to considerable reduce the costs and the space required .

6.6 Controller software

In contrast to analogue electronic control circuitry, which operates continuously, digital electronic control circuitry is characterised by a timed mode of operation, in which the complete control program is repeated at short intervals.

Sensing time

Sensing time (= interval between two sensing operations) is constant. Once per sensing period the micro processor carries out the following operations:

- Reading in of new input variables
- Calculation of manipulated value based on new input variables
- Output of new manipulated variable

In contrast to an analogue controller, the characteristic of the controller output variable is not continuous but has a step-like form..

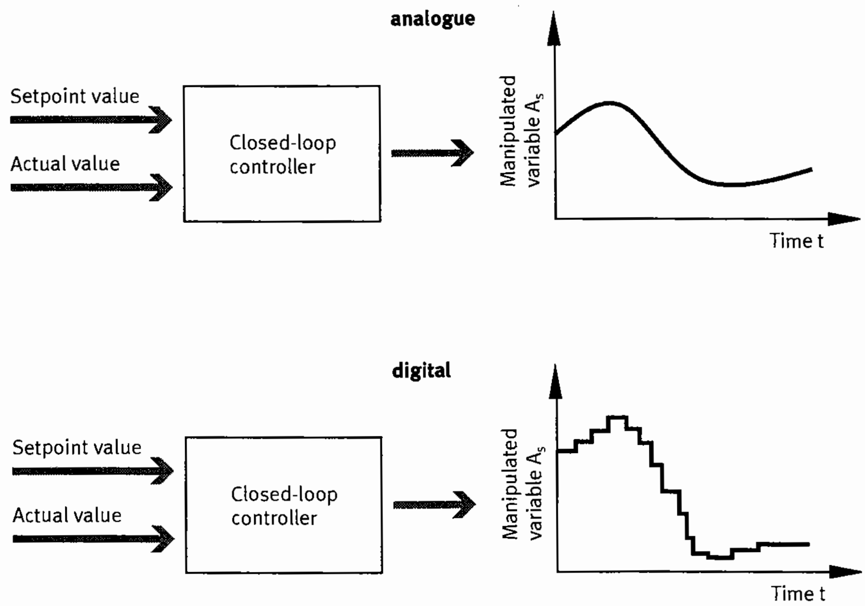


Fig. B6.5: Controller output signal for analogue and digital closed-loop control

If sensing is carried out only occasionally, a new manipulated variable will be generated by the micro controller only at lengthy intervals. The drive will thus be activated with „obsolete“ manipulated variables. This results in lower control quality. If sensing time is too long, the controller will become unstable and will oscillate continuously.

Consequences are: The faster the controlled system, in this case the servo-pneumatic drive, reacts to changes in the manipulated variable, the faster sensing must be carried out.

Sensing times of 1 to 3 milliseconds have proved beneficial with servo-pneumatic drives. This means that a new manipulated variable is calculated three hundred to one thousand times a second, and the valve is activated with a new value..

Closed-loop control program

The closed-loop control program is used to calculate the manipulated variables continuously from the two input variables, namely setpoint position value X_{setp} and actual position value X_{act}. This program is derived from the triple-loop controller structure (Fig. B6.2).

This is carried out in two steps.
- The control algorithm is formulated, based on the signal flow chart (Fig. B6.2). The information contained in the signal flow chart is represented in the control algorithm as a sequence of calculation formulae and statements. Fig. B6.6 illustrates the algorithm for the triple-loop control.
- The control algorithm forms the basis for the actual control program. The algorithm in itself is very similar to a program in a user-oriented programming language such as Fortran, Pascal or C. A control program can thus be generated from the control algorithm with relatively little effort.

Note on control programs

A control program is automatically started as soon as the system is switched on. Therefore, users do not need to generate a control program themselves!

Control algorithm

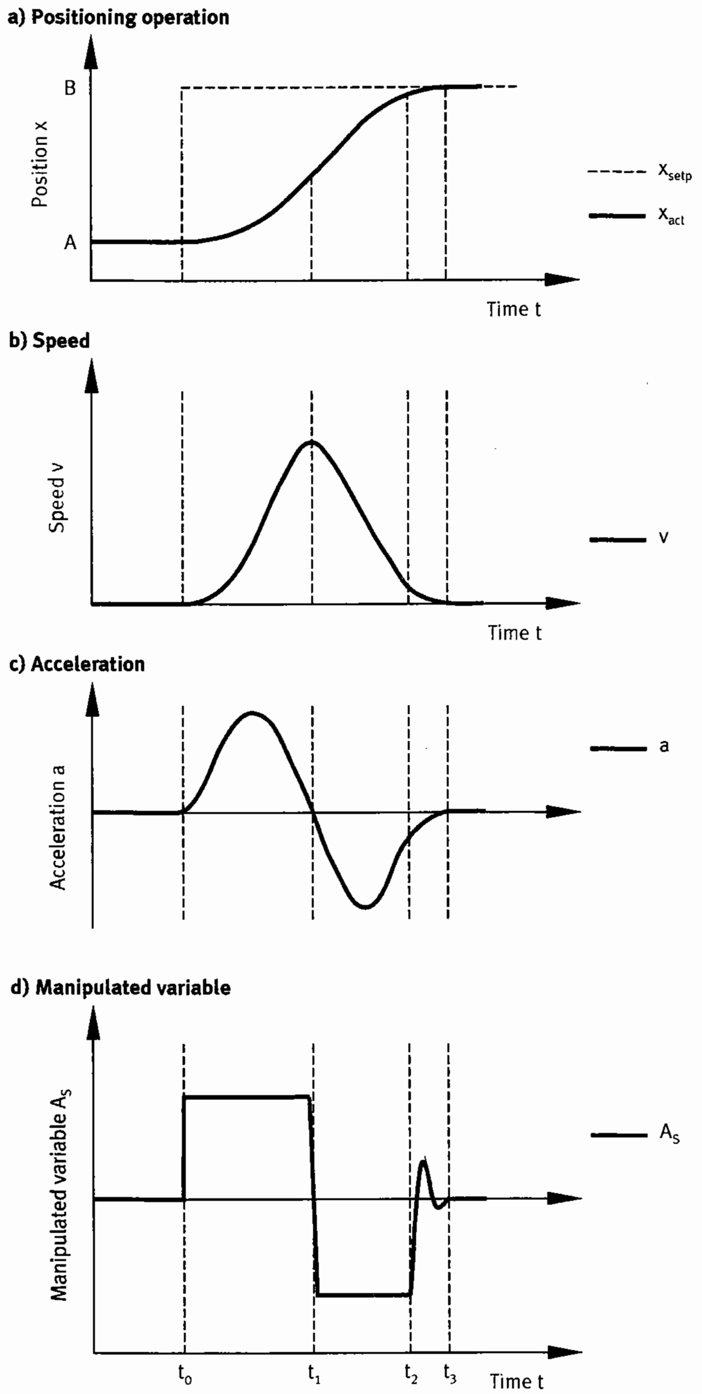
```
Repeat control algorithm for each sensing step.

Start of control algorithm.

Read-in setpoint position value.
Read-in actual position value.

Calculate speed.
Calculate acceleration

Position deviation = Setpoint position value – actual position value

Sum     =     Position deviation * Kx
              –     Speed * Kv
              –     Acceleration * Ka

Manipulated variable   =   Sum

If the sum is greater than the upper manipulated variable limit,
then the manipulated variable = upper manipulated variable limit.

If the sum is less than the lower manipulated variable limit,
then the manipulated variable = lower manipulated variable limit.

Output manipulated variable.

End of control algorithm
```

Fig. B6.6:Control algorithm

6.7 Step-response of a pneumatic NC axis

Figs. B6.7a to B6.7d show the reaction of the position control loop to a step change in the setpoint value x_{setp} from A to B. They show the following:

- the time curve for piston position x_{act} (Fig. B6.7a)
- the time curve for piston speed v (Fig. B6.7b)
- the time curve for piston acceleration a (Fig. B6.7c)
- the time curve for the manipulated variable A_s, used to activate the valve(Fig. B6.7d)



t_0 bis t_1: Acceleration phase
t_1 bis t_2: Retardation phase
t_2 bis t_3: Settling phase

Fig. 6.7: Step response of a servo-pneumatic drive

Three motion phases can be distinguished (Fig. B6.7):

- Acceleration phase: Directly after the change of the setpoint position value, the position deviation is very large. Due to this large position deviation, the maximum manipulated variable is first output, i.e. the valve is opened fully. This causes the piston of the positioning cylinder to accelerate hard, reaching a high travel velocity (acceleration phase in Fig. B6.7). The difference between the setpoint position value and the actual position value decreases due to the high travel velocity. At the same time the speed-proportional controller component becomes larger and larger as the drive speed increases.
- Retardation phase: At the point in time t1 the component of the speed-proportional manipulated variable becomes larger than the component porportional to the position deviation (ref. Fig. B6.2). Since both components act in opposite directions the valve is reversed at this point in time. This causes the pressurised cylinder chamber to be exhausted, while the previously exhausted chamber is pressurised. Since the valve is once again fully opened, a large pressure difference is created very quickly. The piston together with the attached load is retarded..
- Settling phase: The valve is again actuated in the same direction as in phase 1. The pressure difference required to retard piston and load will be dissipated. This will prevent rebounding of the cylinder piston. The precise controlability of the valve permits exact compensation for the pressure difference and piston deviation still present.

6.8 Processing of a numerical control program

In case of a numerically controlled axis, the motion of the axis is specified by means of the program. This is carried out via the numerical controller, the axis controller and the mechanical components of the axis.

This operation will be explained by means of an example (Fig. B6.8).

- Fig. B6.8a shows two commands of the NC program.
- Fig. B6.8b shows the positioning operation in graphic illustration.
- Fig. B6.8c shows the range on either side of the target position on an enlarged scale.

a) Program commands

```
N10 G61 X3
N20 G00 G90 X200
```

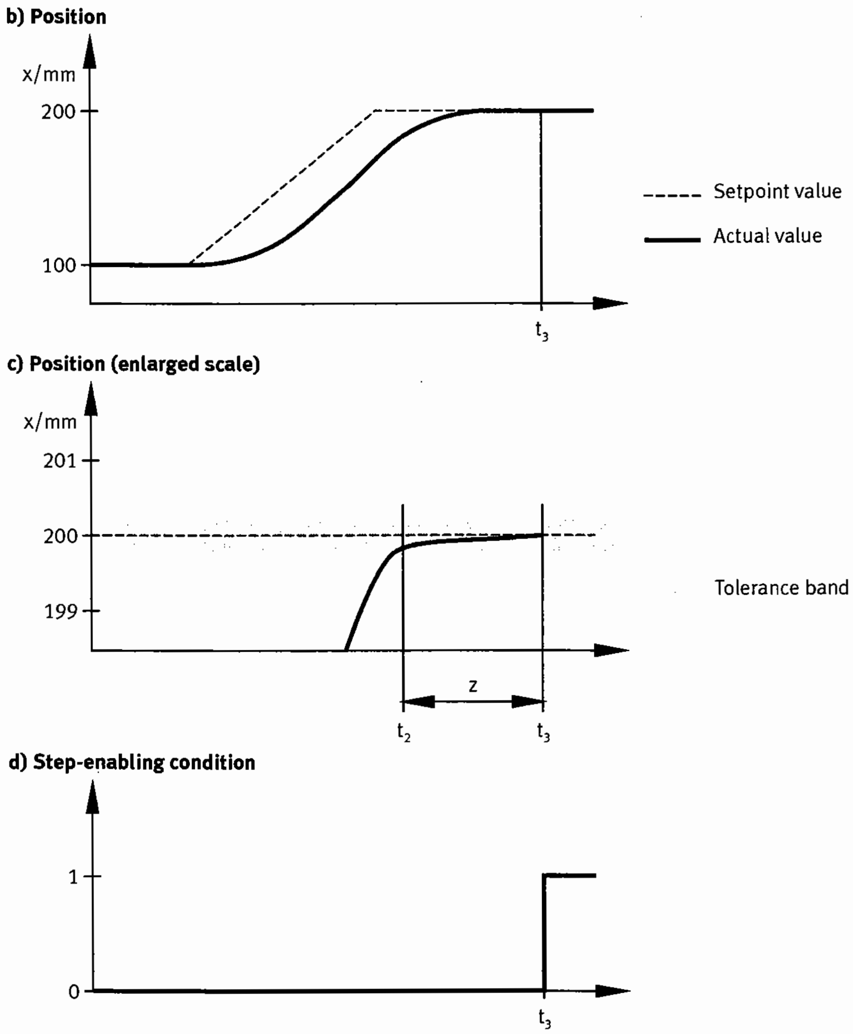


Fig. B6.8: Processing of two NC-program steps

The first command (Fig. B6.8a) sets the positioning quality class (in this case to precise stop without transient response), i.e. without resulting axis movement.

The 2nd command (Fig. B6.8a)is executed in the following sequence:

- At the point in time t1, the new setpoint position value is specified by the numerically controlled axis (200 mm, Fig. B 6.8b).
- The position controller then acts to bring the actual position value close to the setpoint position value.
- At the point in time t2, the deviation between the setpoint position value and the actual position value is for the first time smaller than the permissible positioning tolerance (in this case 0.25 mm).
- A check is made within monitoring period z to check whether the position remains within the tolerance band (Fig. B6.8). If this condition is fulfilled for the specified period z, the signal „position reached" is set at the point in time t3. Period z is dependent on the selected cylinder and load.

The positioning operation is thus concluded and the next command of the motion program can be executed.

Control of handling devices with several NC axes

In applications with several numerically controlled axes, a program step is completed only when all the axes have reached their target positions. The flow chart (Fig. B6.9) shows the interaction between the numerical controller and the axis controllers of a device with two axes.

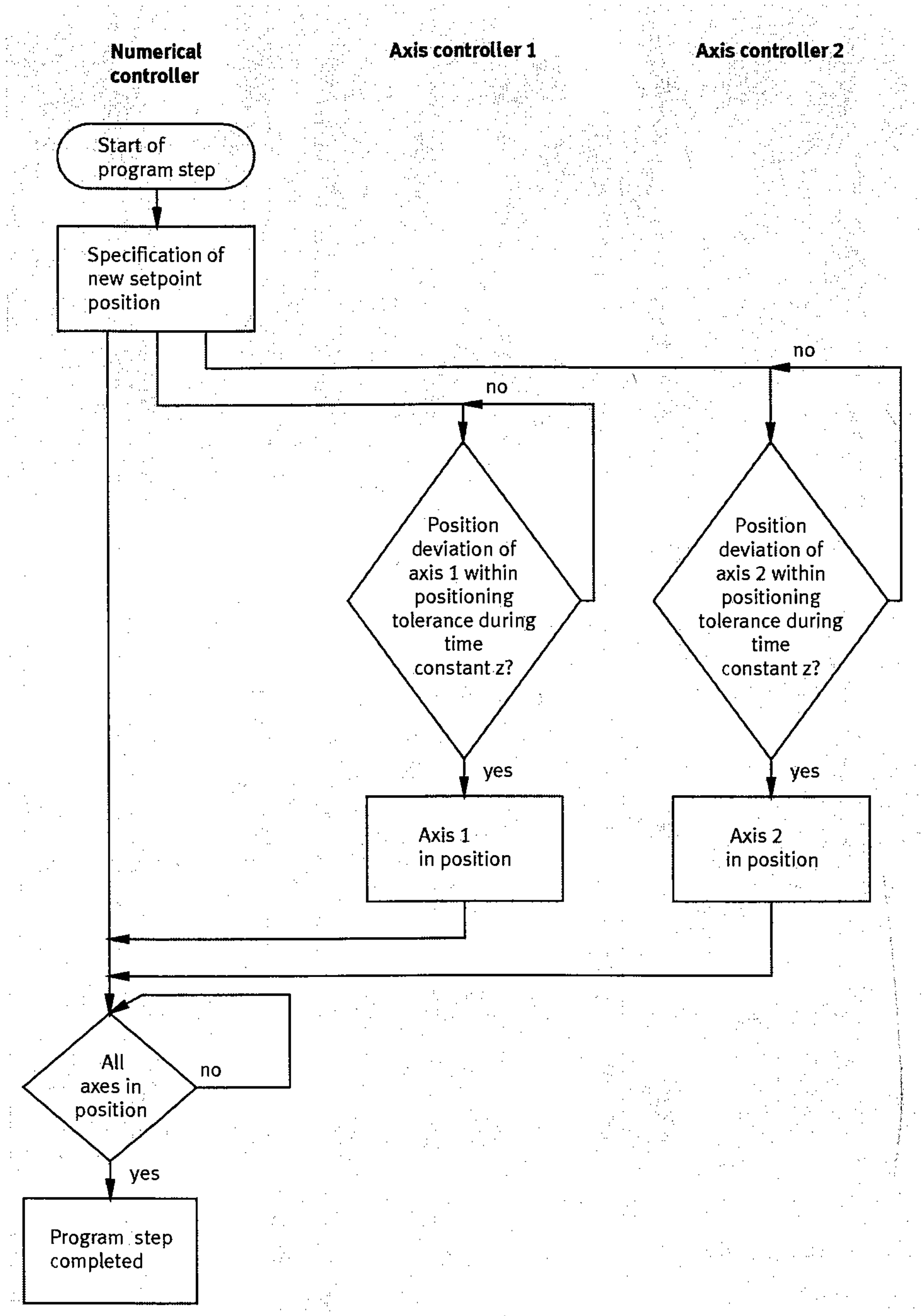


Fig. B6.9: Processing of a program step using a device with two NC axes

6.9

Application example: Motion cycle of a packaging device

Fig. B6.10a shows a packaging machine (ref. Fig. B5.11). The two axes must be positioned to an accuracy of 1 mm for the packaging operation.

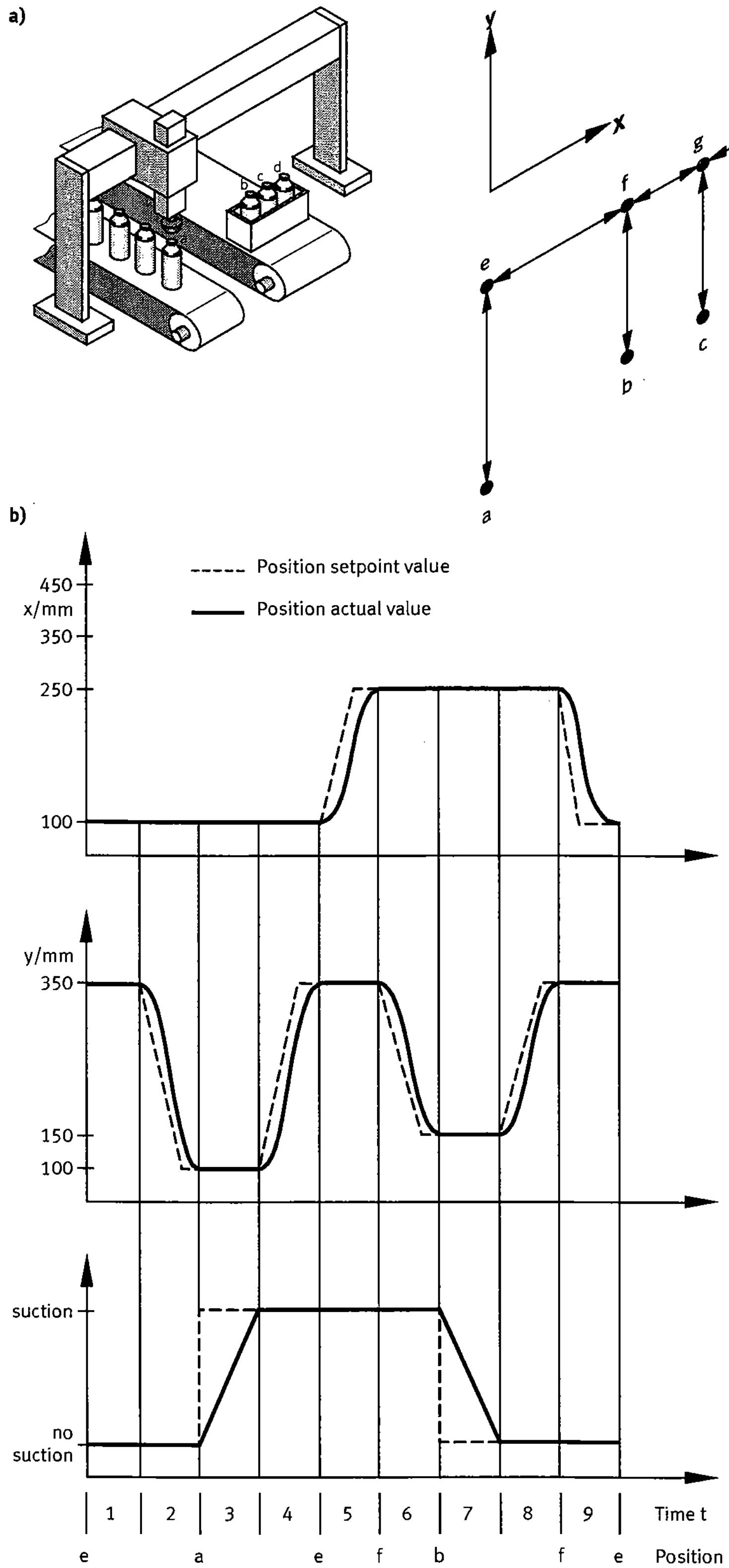


Fig. B6.10: Application example packaging device

Motion sequence

The motion sequences of both axes and the suction cup status are shown in Fig. B6.10b.

- Step 1:
  The gripper is in position e (position of x-axis: 100 mm, position of z-axis: 350 mm).
- Step 2:
  With the first command of the NC program, position a is approached (see fig. B5.12). The position setpoint value for the z-axis is changed from 350 mm to 100 mm. The proportional valve is actuated via the controller in such a way as to cause the z-axis to move downwards. If the system deviation has become smaller than the positioning tolerance, the signal "Position reached" is set. The NC controller switches to the next step.
- Step 3:
  The suction cup is actuated. This is followed by a short interval to ensure that the bottle is securely held by the suction cup.
- Step 4:
  Position e is approached again. The bottle is lifted.
- Step 5:
  The bottle is moved in horizontal direction from position e to position f.
- Step 6:
  The bottle is deposited (position b).
- Step 7:
  The suction cup is released.
- Step 8:
  The y-axis traverses upwards towards position f.
- Step 9:
  The x-axis traverses to position e.

The excerpt of the motion sequence shown in fig. B6.10 ends here.

Part C

Part C Solutions

Solution 1
Setting up a servo-pneumatic axis

Problem definition

- Assembling the equipment
- Setting up the pneumatic circuit
- Setting up the electrical circuit
- Checking the overall set-up

Solution description

The servo-pneumatic linear axis will have been set-up and wired fully if you have performed all steps described in the procedure.

Caution

The system may not be switched on yet!

Solution 1

Solution 2
Equipping PC boards via "pick and place"

Problem definition

- Installing WinPISA
- Putting the WinPISA-controller interface into operation
- Putting the linear axis into operation electrically and pneumatically
- Remedying any faults which occur
- Checking the control direction

Solution description

Commissioning
The function test will have been successfully performed if
- WinPISA has been installed and runs on the PC
- the connection between PC and controller is operating correctly
- the control direction is correct and
- the slide can be moved with the motion test throughout the entire traversing range.

	Manipulated variable (Movement of the slide on the screen to the left)	**Manipulated variable (Movement of the slide on the screen to the right)**
Test 1	4.72 V	5.34 V
Test 2	4.68 V	5.30 V
Test 3	4.74 V	5.34 V

Table C2.1: Function test of the proportional valve

Interpreting the results

- There is a manipulated variable range in which the axis does not traverse.
- The values determined differ for various linear axes. (Production tolerances on the proportional valve and friction of cylinder and linear guide).
- The manipulated variables determined should be subject to only small discrepancies within the 3 tests.

Solution 2

Solution 3
Filling a pallet

Problem definition

- Creating the project
- Configuring the project
- Writing the motion program
- Testing the motion program

Solution description

The exercise will have been successfully performed if the slide approaches the 3 positions in the right order and at the required speed. The required programs are printed below.

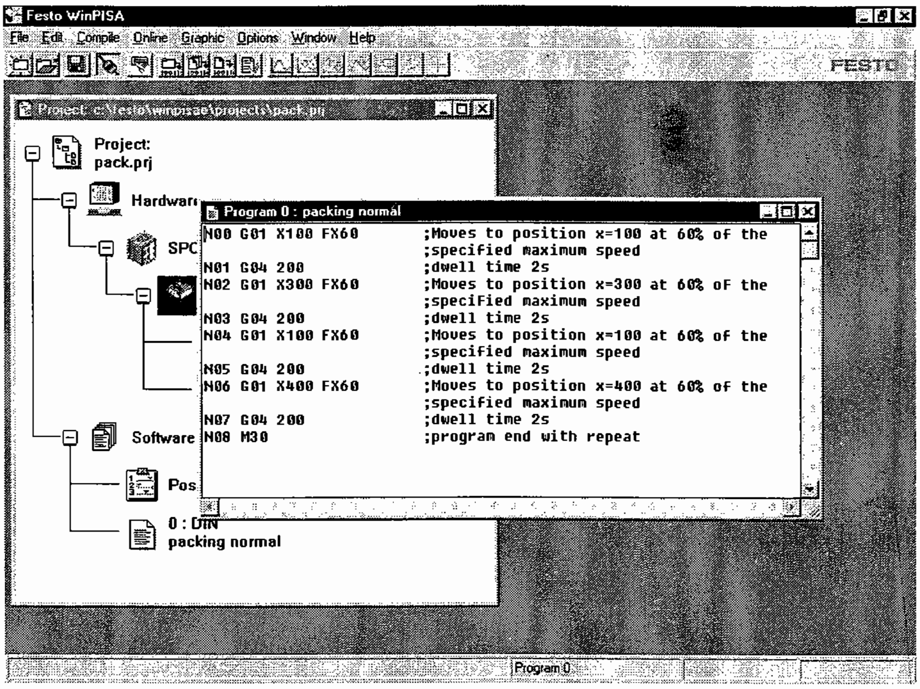


Figure C3.1: NC program (project Package)

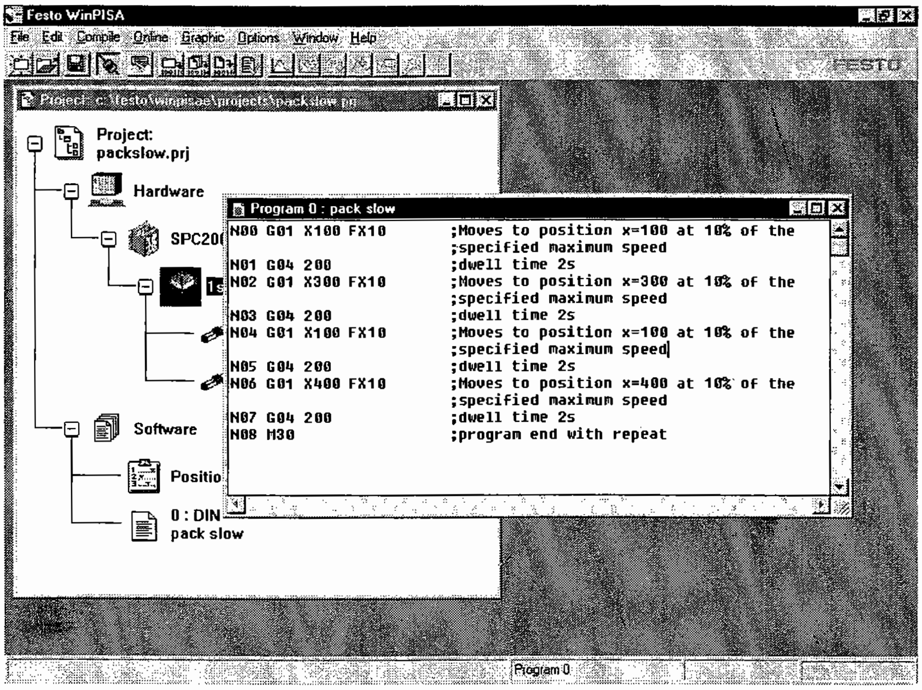


Figure C3.2: NC program (project Package)

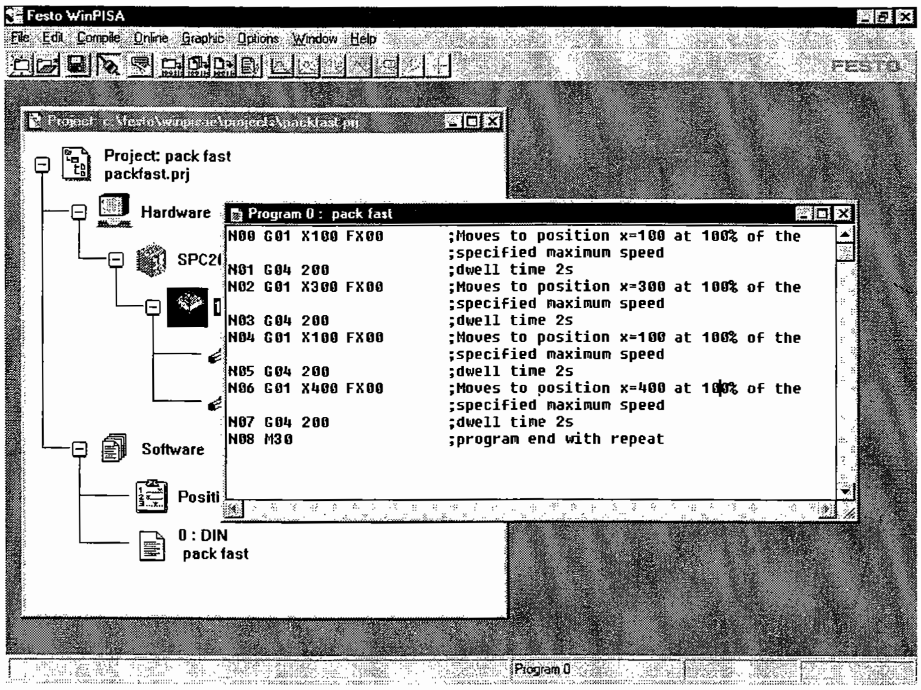


Figure C3.3: NC program (project Package)

Solution 4
Sorting gear wheels

Problem definition

- Writing an NC program
- Testing the program via WinPISA
- Remedying an EMERGENCY-STOP situation via WinPISA
- Operating an axis using the controller control panel
- Remedying an EMERGENCY-STOP situation using the controller control panel

Solution description

1., 2., 3. Writing and testing the project and program

Points 1 to 3 of the procedure will have been successfully performed if the program runs error-free.

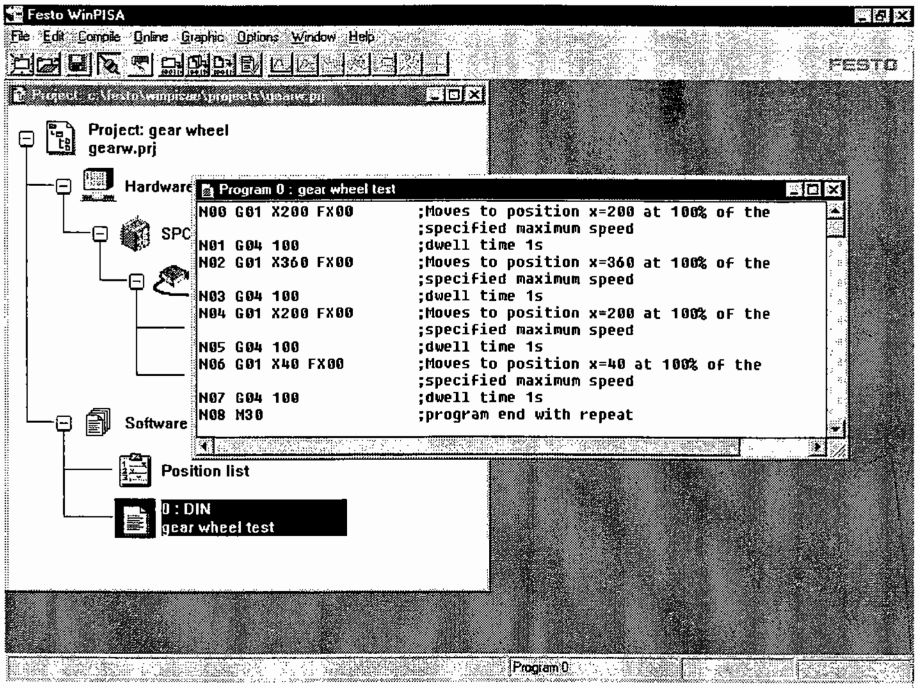


Figure C4.1: NC program (project Gear Wheels)

4. Remedying an EMERGENCY-STOP situation via WinPISA
In the case of EMERGENCY-STOP, it is necessary to disconnect the compressed air supply for reasons relating to safety. After the fault has been remedied, pull (unlock) the EMERGENCY-STOP button and reconnect the compressed air.

You must confirm the error message in WinPISA after calling the motion test. This resets the fault on the controller and the red LED on the controller goes out.

5., 6. Operation/Fault-clearance using the controller control panel
The required procedure is described in Section "Technical knowledge", Exercise 4.

Solution 5
Diagnosis on a closed-loop-controlled axis

Problem definition

- Naming the elements and characteristics of a closed control loop
- Recording measured values
- Graphically representing a movement operation

Solution description

1. Signal flow charts

Signal flowchart with elements and characteristics of a closed control loop: See Figure A5.2

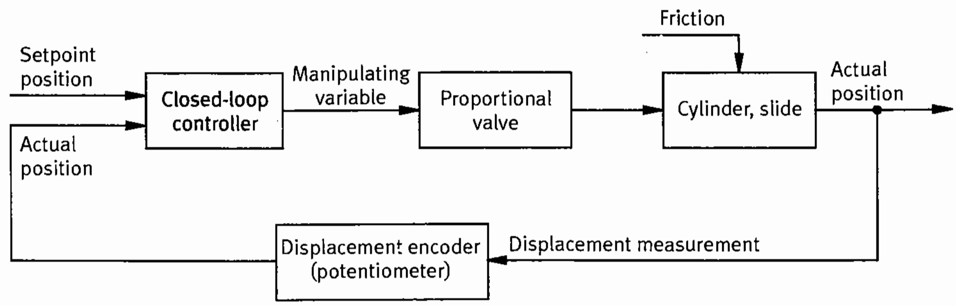


Figure C5.1: Signal flowchart with modules of a servo-pneumatic axis

2., 3. Writing and testing the project and program

Points 2 and 3 of the procedure will have been successfully performed when the program runs error-free.

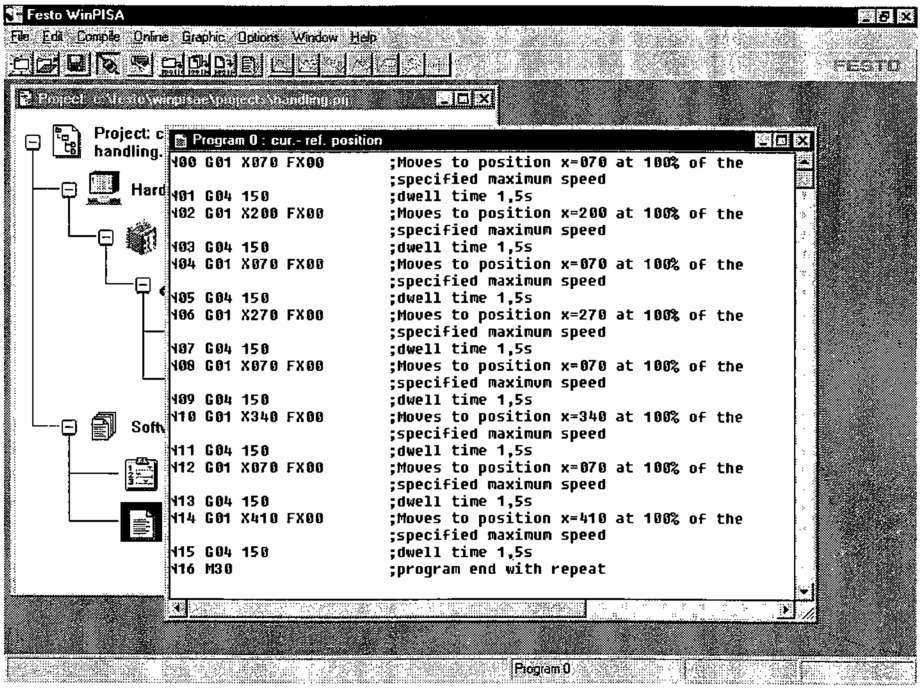


Figure C5.2: NC program (project Handev)

4., 5. Recording, loading and graphically representing measured values

The measured results depend on numerous influencing variables, including the supply pressure and friction of the axis. They may thus differ greatly from the characteristics shown in Figures C5.3 and C5.4.

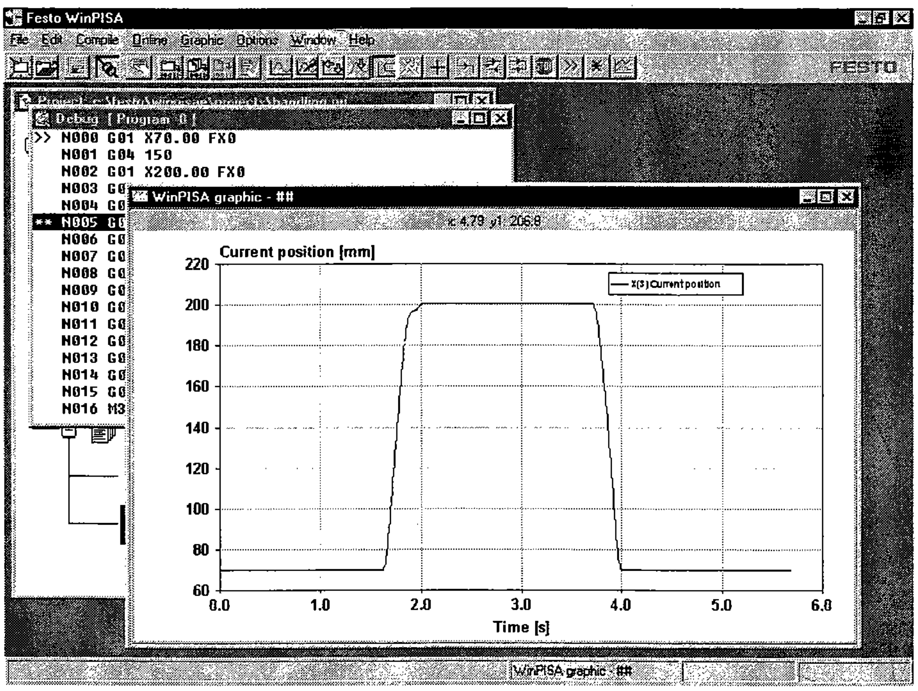


Figure C5.3: Actual position as a function of time

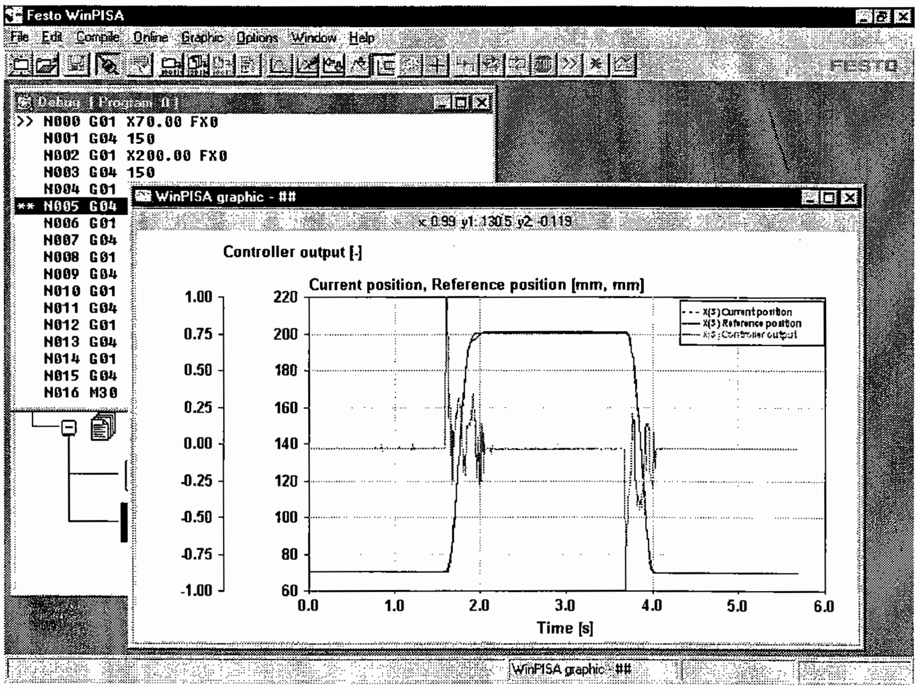


Figure C5.4: Setpoint position and actual position, in addition to manipulated variable, as a function of time

Solution 6
Handling sensitive goods

Problem definition

- Selecting a suitable EMERGENCY-STOP circuit
- Setting up the EMERGENCY-STOP circuit
- Testing the function of the EMERGENCY-STOP circuit
- Comparing the behaviours of different EMERGENCY-STOP circuits

Solution description

1. Writing and testing the project and program

This point will have been successfully performed if the program runs error-free.

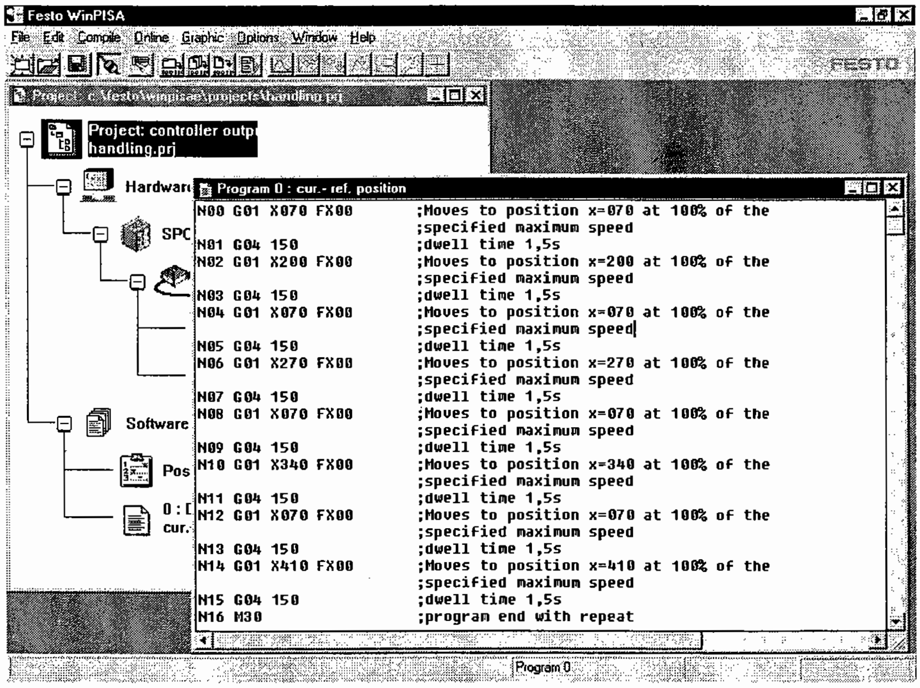


Figure C6.1: NC program (project Handev)

2. Selection of a suitable EMERGENCY-STOP circuit
Circuits that move the slide against a stop in the case of EMERGENCY-STOP are unsuitable

- because the jars to be transported may be damaged or destroyed in the case of EMERGENCY-STOP
- because collision with the box may occur if vertical feed has just been lowered.

The two circuits shown in Figure A6.3 resp. 6.4 are suitable because they ensure that the slide is decelerated immediately when EMERGENCY-STOP is pressed.

3., 4. Setting up and testing the circuits
The following applies to both circuits:

- If the EMERGENCY-STOP button is not pressed, the slide must move in the same way as without the additional EMERGENCY-STOP circuit.
- If the EMERGENCY-STOP button is pressed, the slide must stop after a short stopping distance.

5. Comparison of various EMERGENCY-STOP circuits
In the case of both circuits, pressing EMERGENCY-STOP leads to rapid deceleration of the slide. There are no apparent major differences in braking behaviour owing to the relatively low moving mass.

Solution 7
Setting up a gantry system with servo-pneumatic drives

Problem definition

- Assembling the equipment
- Setting up the pneumatic circuit
- Setting up the electrical circuit
- Checking the overall set-up

Solution description

The gantry will have been fully set up and wired if you have performed all steps of the procedure carefully.

Caution

System may not be switched on yet!

Solution 7

Solution 8
Commissioning a twin-axis gantry

Problem definition

- Putting the WinPISA-controller interface into operation
- Putting the linear axes into operation electrically and pneumatically
- Remedying any faults which may occur
- Checking the control direction of both axes
- Checking the EMERGENCY-STOP behaviour of both axes

Solution description

The function test will have been successfully conducted if

- WinPISA is installed and runs on the PC
- the connection between PC and controller is operating correctly
- the control direction of both axes is correct
- both slides can be moved with the motion test over the entire traversing range
- both axes demonstrate the required EMERGENCY-STOP behaviour

Solution 9
Configuring a machining station

Problem definition

- Creating the project
- Configuring the project for the twin-axis gantry
- Performing identification on the twin-axis system

Solution description

The exercise will have been successfully performed
- if the project is fully configured in WinPISA
- if all parameters have been entered in the right way (axis parameters and application parameters for both axes)

if the static and dynamic identification has been performed for both axes (x and y)

Solution 9

Solution 10
Unloading a pallet

Problem definition

- Creating and configuring the project
- Writing the position list
- Writing the motion program
- Testing the motion program
- Optimising the traversing speed

Solution description

The exercise will have been correctly performed when the slide approaches the required position in the right sequence. An example program (for command G01) with related position list is printed below. The names and the location of the positions may vary.

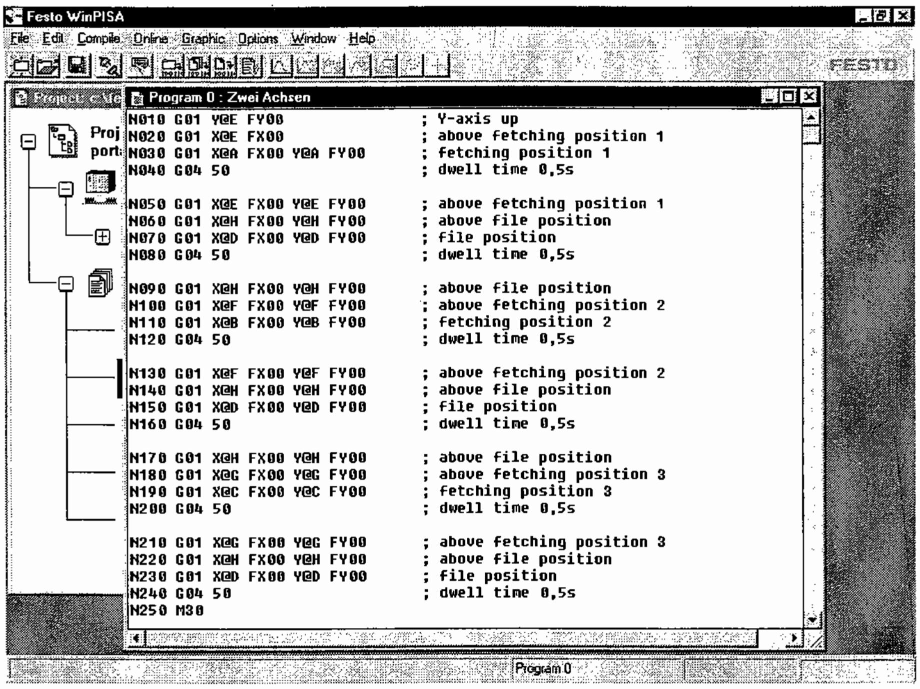


Figure C10.1: NC program (project Pick)

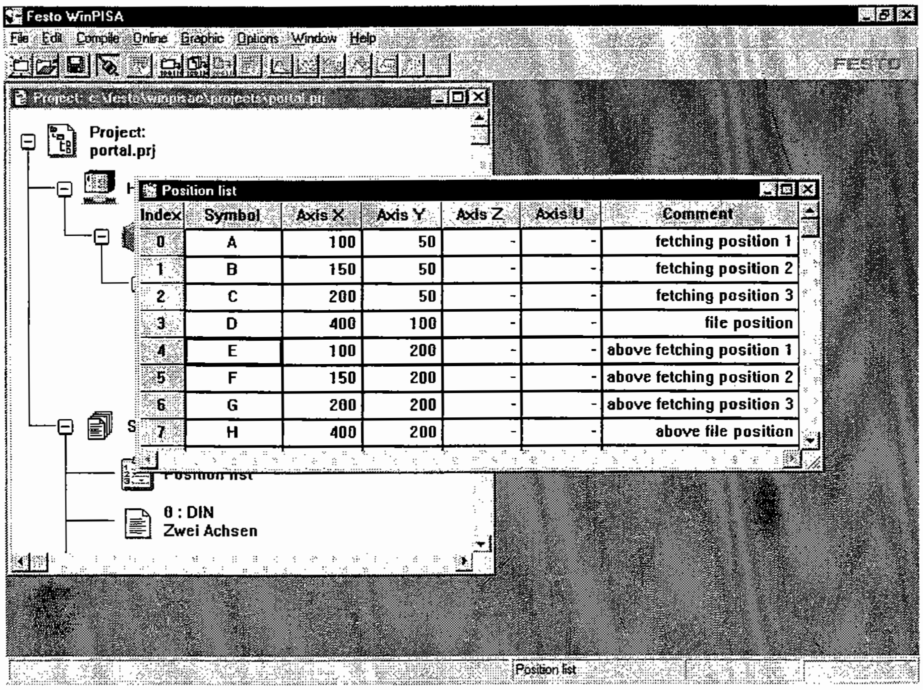


Figure C10.2: Position list (project Pick)

Solution 11
Assembling and commissioning a gripper

Problem definition

- Mounting the gripper components
- Adding to the pneumatic circuit
- Adding to the electrical circuit
- Commissioning the system

Solution description

The gantry with gripper will have been fully set up, wired and put into operation if you have performed all steps of the procedure carefully.

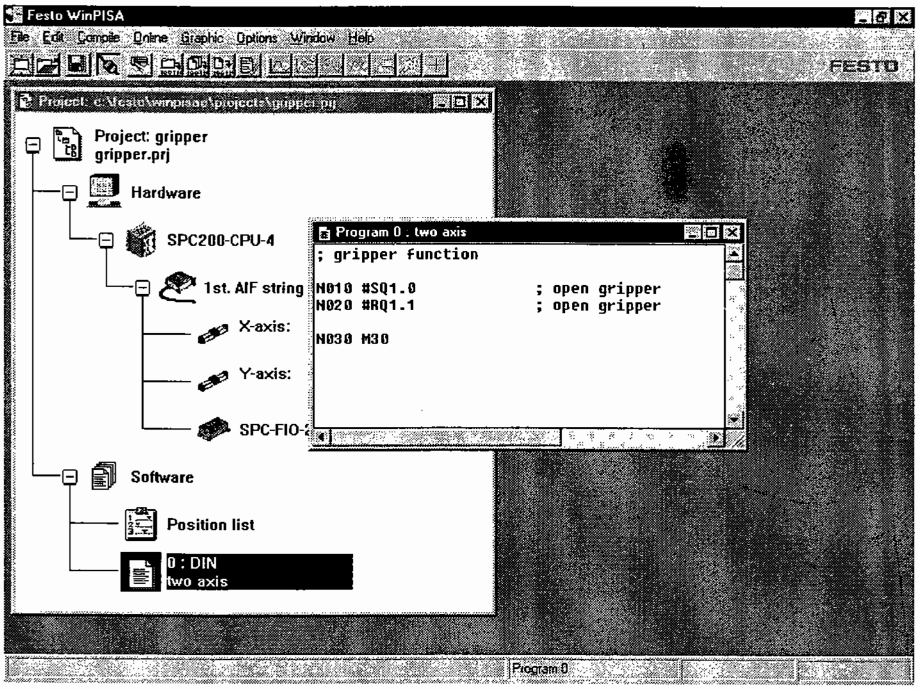


Figure C11.1: Test program: Open gripper

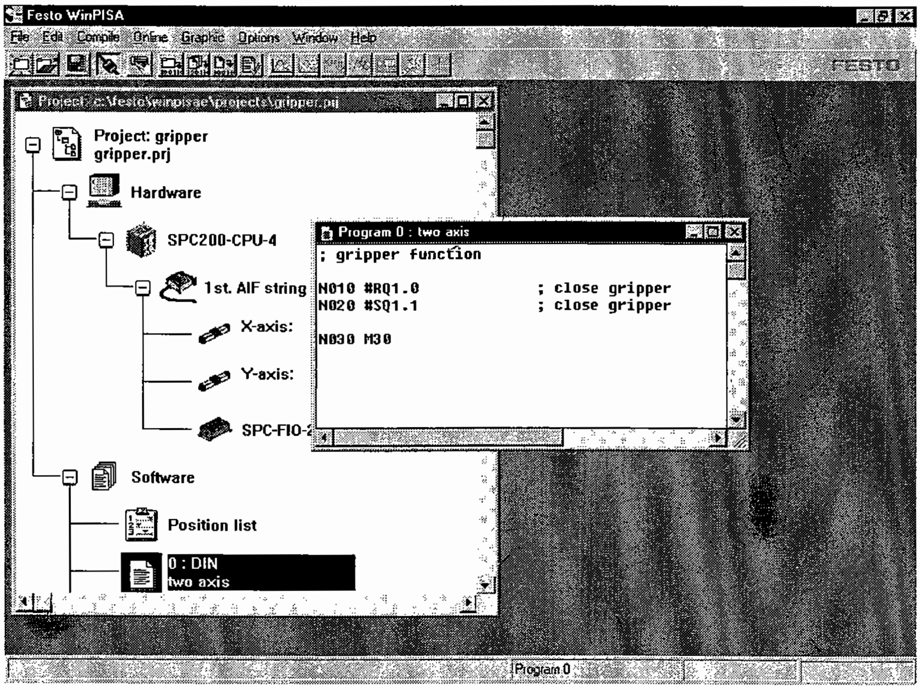


Figure C11.2: Test program: Close gripper

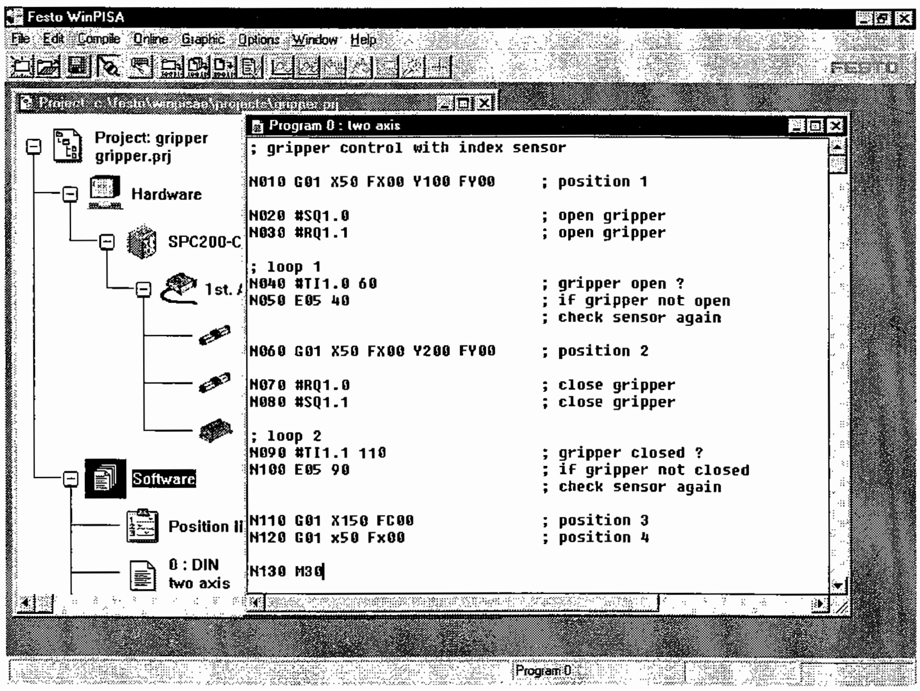


Figure C11.3: Test program gripper actuation and monitoring, x and y axis

Solution 12
Packing accessory parts for flat-pack furniture

Problem definition

- Creating and configuring the project
- Writing the motion program
- Testing the motion program
- Optimising the traversing speed

Solution description

The exercise will have been correctly performed

- If the slide approaches the required positions (project Package)
- If the slide approaches the positions via skipping (project Package1)

An example program for project Package1 is printed below.

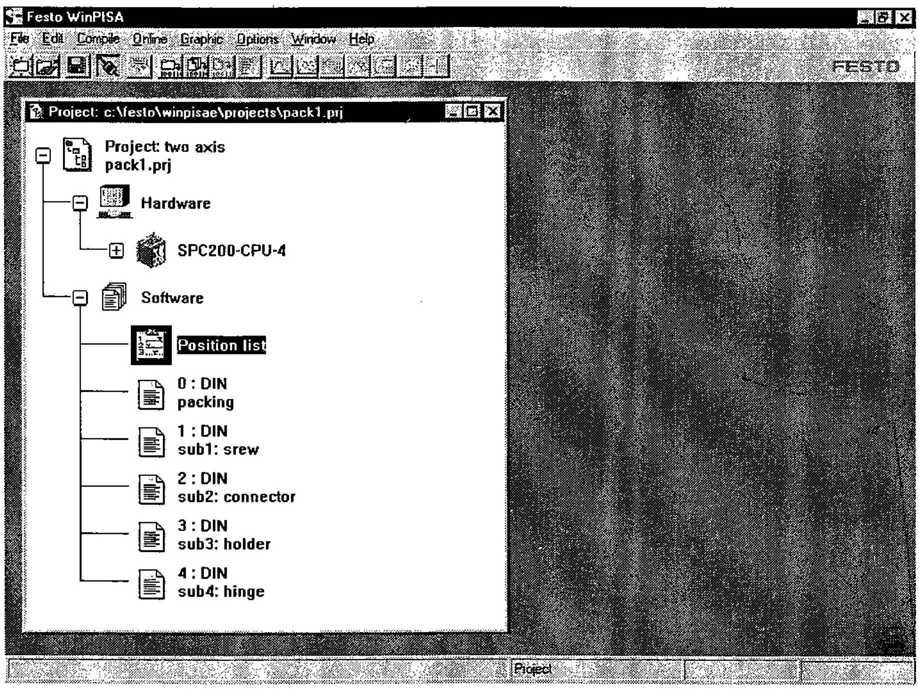


Figure C12.1: Project Package1

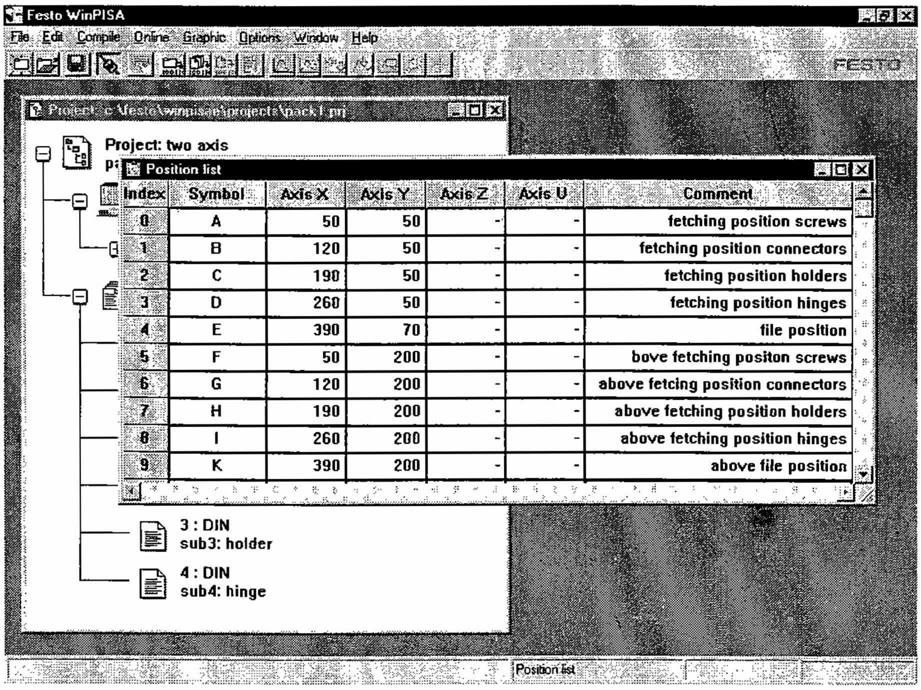


Figure C12.2: Position list (project Package1)

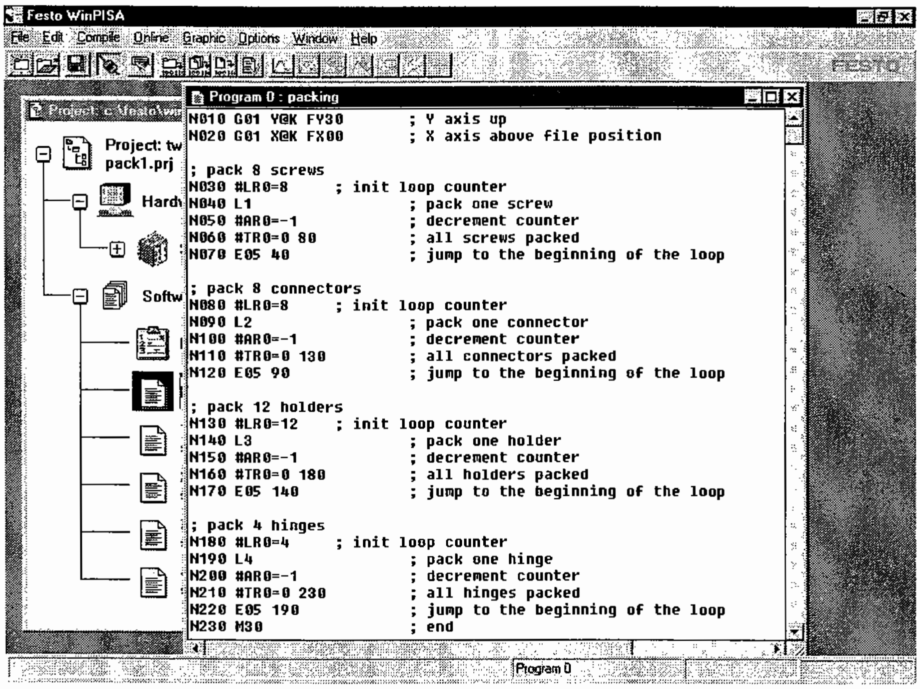


Figure C12.3: NC main program (project Package1)

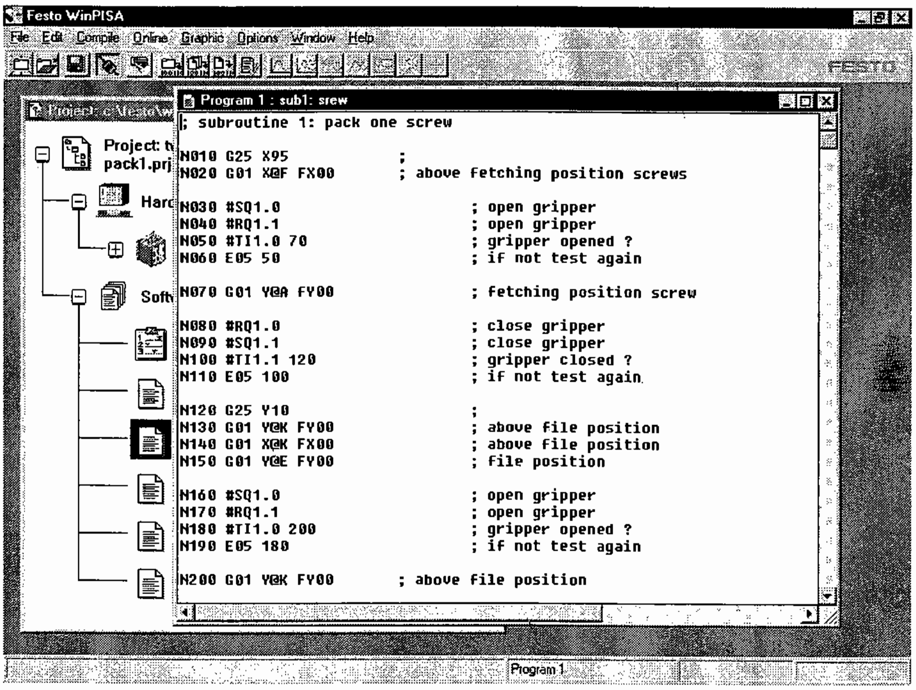


Figure C12.4: NC subroutine 1 (project Package1)

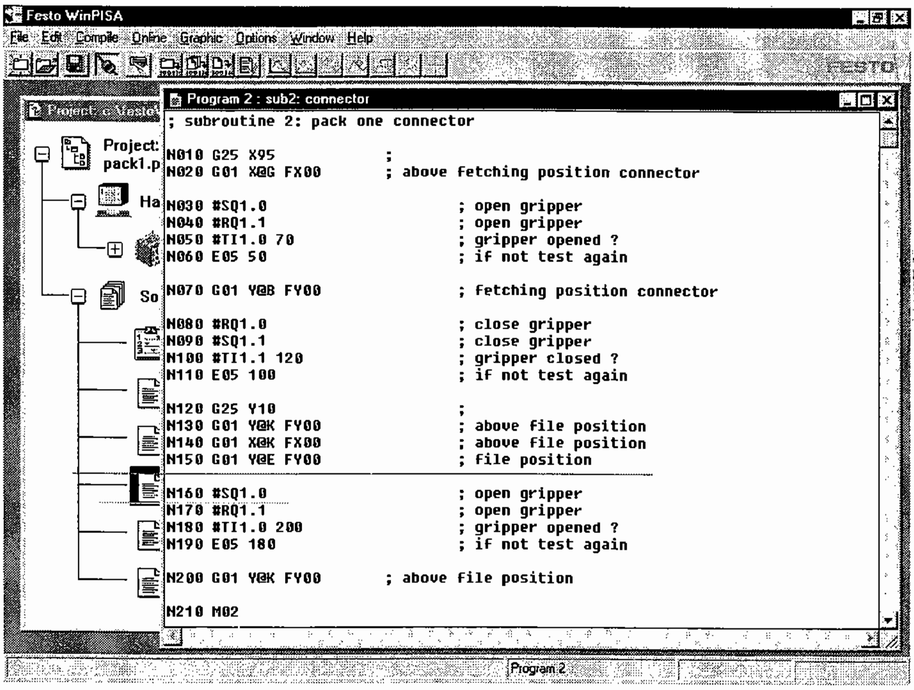


Figure C12.5: NC subroutine 2 (project Package1)

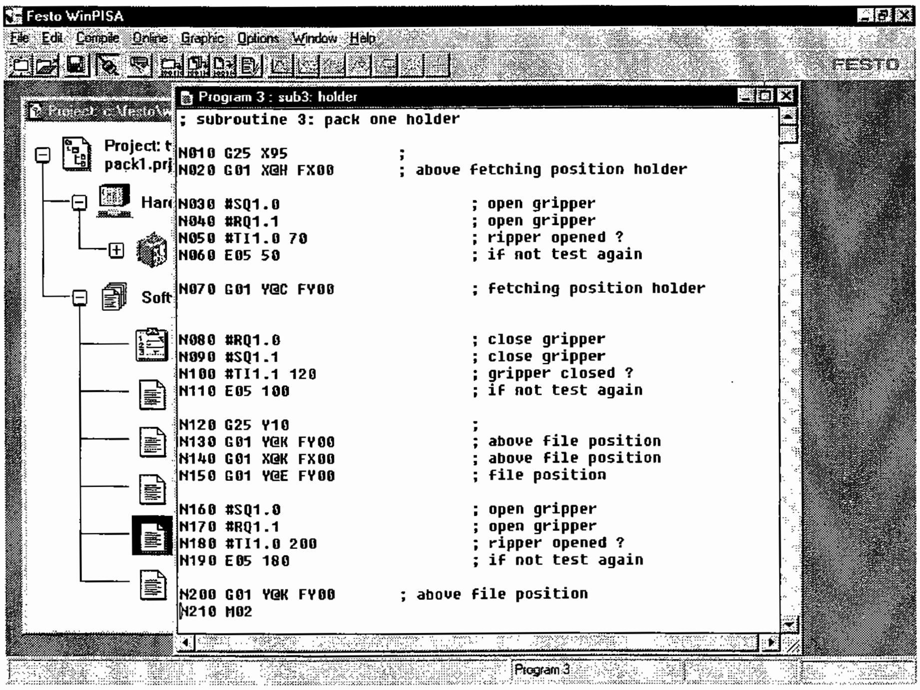


Figure C12.6: NC subroutine 3 (project Package1)

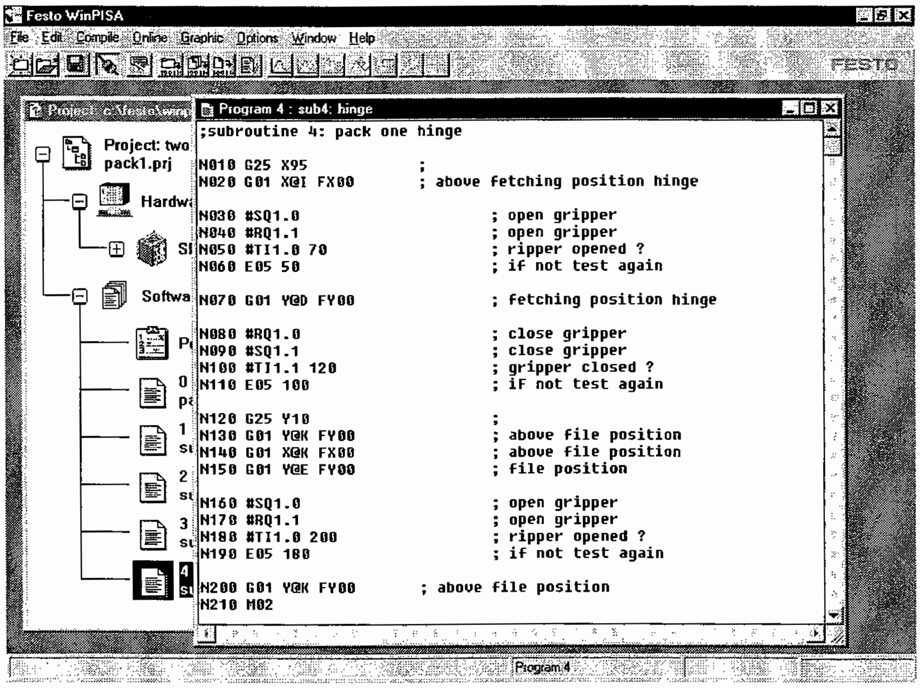


Figure C12.7: NC subroutine 4 (project Package1)

Part D

Part D Appendix

Safety recommendations

For your own safety, please observe the following instructions:

- Screw the components securely to the profile plate.
- Switch off the compressed air supply immediately if tubing becomes detached in order to prevent accidents.
- Do not exceed the maximum permissible working pressure of 8 bar.
- Switch on the compressed air supply only when all tubing connections have been made and are secure.
- Be especially careful when switching on the compressed air supply. Cylinders may advance or retract unexpectedly.
- Never uncouple tubing when pressurised.
- Observe also the general safety rules in accordance with DIN 58126 and VDE 100.
- Use only extra-low voltage supplies, maximum 24 Volt DC.
- Check the pneumatic lines and also the electrical cables and connections before commissioning the controller.
- Please note that the slide incorporates powerful magnets. Therefore, keep all diskettes and other objects sensitive to magnetic fields at a safe distance from this unit.

Observe the data sheets for the individual components, particularly all instructions relating to safety.

Equipment set

Basic equipment set
PneuPos 1
Order No. 192490

Designation	Order No.	Quantity
Shock absorber	034572	2
Plastic tubing, 5 m, PUN 3 x 0.5	197118	1
Plastic tubing, 10 m, PUN 4 x 0.75	151496	1
Plastic tubing, 5 m, PUN 6 x 1	152963	1
Displacement encoder	152628	1
Mounting kit for displacement encoder	178441	1
3/2-way solenoid valve with LED, normally closed position	167073	1
Axis controller SPC 200/P01 with control panel	170521	1
EMERGENCY-OFF pushbutton, electrical	183347	1
Accessories for axis controller	192491	1
5/3-way proportional valve	192493	1
Axis interface for potentiometer	192494	1
EMERGENCY-OFF function	192495	1
Linear drive, pneumatic	192501	1
Measuring lead, 1500 mm, blue	376940	2
Measuring lead, 1500 mm, red	376941	2

Accessories

Designation	Order No.	Quantity
Workbook „Servopneumatic Positioning", German	192503	1
Workbook „Servopneumatic Positioning", English	196949	1
Programming software WinPISA, German	170095	1
Programming software WinPISA, English	170097	1
Manual for axis controller SPC 200, German	170245	1
Manual for axis controller SPC 200, English	170246	1
Service unit with fine filter 5 µm	526337	1
Aluminium profile plate, 700 x 700 mm	159410	1
Assembly accessories for cables, tubes	526338	1
Table power supply unit, DE	162417	1
Table power supply nit, other countries	on request	1

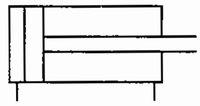
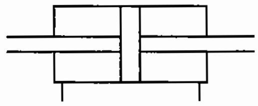
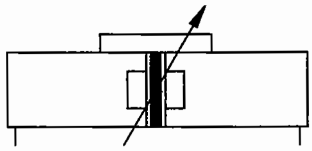
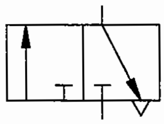
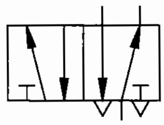
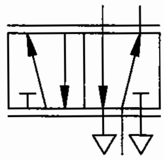
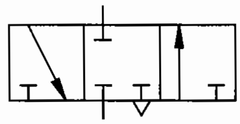
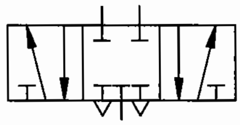
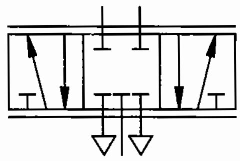
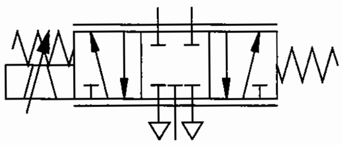
Supplementary equipment set
PneuPos 2
Order No.. 192496

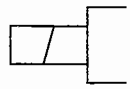
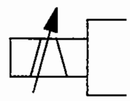
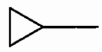
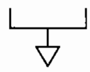
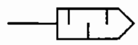
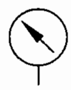
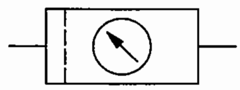
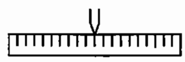
Designation	Order No.	Quantity
Plastic tubing, 5 m, PUN 3 x 0.5	197118	1
Plastic tubing, 10 m, PUN 4 x 0.75	151496	1
Plastic tubing, 5 m, PUN 6 x 1	152963	1
5/3-way proportional valve	192493	1
Linear drive, pneumatic, with integrated displacement encoder	192497	1
Axis interface for linear drive	192498	1
Gantry kit	192500	1

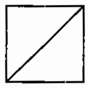
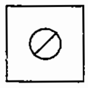
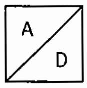
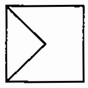
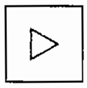
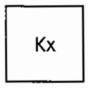
Supplementary equipment set
Gripper
Order No. 192502

Designation	Order No.	Quantity
I/O extension	395502	1
Parallel gripper kit, complete	395503	1

List of symbols

Designation	Note	Symbol
Double-acting cylinder	with single-ended piston rod	
Double-acting cylinder	with through piston rod	
Double-acting cylinder	without piston rod, directly coupled	
3/2-way valve	normally closed position	
5/2-way valve	with two outlet lines	
5/2-way servo valve	with two outlet lines	
3/3-way valve	mid-position closed	
5/3-way valve	mid-position closed	
5/3-way servo valve	mid-position closed	
5/3-way servo valve	mid-position closed, spring centered, electrically actuated and infinitely adjustable in both directions	

Designation	Note	Symbol
Mechanical actuation	by spring	
Electrical actuation	by solenoid with 1 winding	
Electrical actuation	by solenoid with 2 opposed windings, infinitely adjustable	
Pressure source		
Working line	Line for transmission of fluid power	
Electrical line	line for transmission of electrical power	
Outlet port	with threaded connection	
Silencer		
Pressure gauge		
Service unit	comprising filter, pressure regulating valve, pressure gauge and lubricator	
Displacement encoder		

Designation	Note	Symbol
Converter	general	
Transducer, signal converter		
Digital/analogue converter		
Controller		
Control amplifier	general	
Control loop component	marked with characteristic data	
Control loop component	marked with transmission characteristics	
Limiter	marked with characteristic curve	

List of applicable guidelines and standards

DIN ISO 1219	Fluid systems and equipment, symbols
DIN 1319 Part 1	Basic terminology of measuring technology: Measuring, counting, testing
DIN 1319 Part 2	Basic terminology of measuring technology: Use of measuring equipment
DIN 19221	Measurement and control: Formulae symbols used in control technology
DIN 19222	Measurement and control: Instrumentation and control, terminology
DIN 19225	Measurement and control: Designation and classification of controllers
DIN 19226	Closed-loop and open-loop control technology: Terminology and designations
DIN 19227	Measurement and control: Graphic symbols and code letters for process instrumentation and control
DIN 19231	Measurement and control: Pressure range for pneumatic signal transmission
DIN 19233	Automatic machines, automation: Terminology
DIN 19236	Measurement and control: Optimisation, terminology
DIN 19237	Measurement and control: Open loop control technology, terminology
DIN 19239	Measurement and control, open-loop control technology, programmable logic controllers, programming
DIN 40719 Part 60	Circuit documentation: Production of function charts for measurement and control
DIN 44300	Data processing: Terminology
DIN 66025	Industrial automation: Program structure for alphanumerically-controlled machines

DIN 66201 Part 1	Process computer systems: Terminology
DIN 66217	Coordinate axes and directions of motion for numerically-controlled machines
DIN 66257	Numerically-controlled machines: Terminology
IEC 27-2A	Letter symbols to be used in electrical technology Part 2: Telecommunications and electronics. First supplement
IEC 50 (351)	International Electrotechnical Vocabulary. Automatic control
DIN IEC 381 Part 1	Analogue signals for closed-loop and open-loop control systems, analogue DC signal; identical to IEC 381-1, edition 1982
ISO 3511-3	1984 Process measurement control functions and instrumentations - Symbolic representation - Part 3: Detailed symbols for instrument interconnection diagrams
VDI/VDE 3844	Drives for actuation of final control elements, characteristic data for pneumatic and electro-hydraulic drives
VDI/VDE 3685	Adaptive controllers: Terminology, properties, notes and examples
VDI 2860	Assembly and handling systems, handling functions, handling devices: Terminology, definitions, symbols
EN 60204 Part 1/ DIN VDE 0113 Part 1	Electrical equipment for industrial machinery
DIN IEC 550/ VDE 0113 Part 200	Interfaces between numerical controllers and industrial machinery
VDE 0199/ IEC 73	Colour coding of indicator lamps and pushbuttons

DIN 31000/ VDE 1000	General guidelines for the safe design of technical products
VDI 2854	Safety requirements for automated production plants
DIN 55003	Machine tools, symbols, numerically-controlled machine tools

List of literature

Europa Lehrmittel	Steuern und Regeln im Maschinenbau Europa Lehrmittel Verlag
Europa Lehrmittel	Fachkunde Elektrotechnik Europa Lehrmittel Verlag
Karg, Eduard	Regelungstechnik Vogel Verlag
Schmäing, Eduard	Regelungstechnik in Bildern Vogel Verlag
Reuter, Manfred	Regelungstechnik für Ingenieure Vieweg Verlag
Zerbe, Günther	Regelungstechnik Formeln, Beispiele, Lösungswege, Tabellen TeMa - Verlag
Frei, Bleicher, Leidig	Speicherprogrammierbare Steuerungen Hüthig Verlag Heidelberg
Plagemann, Bernhard	Methoden der Programmierung von SPS Vogel Verlag
Wellenreuther, Zastrow	Speicherprogrammierte Steuerungen 1 SPS Vieweg Verlag
Weck, Manfred	Werkzeugmaschinen Band 3 Automatisierung und Steuerungstechnik VDI Verlag