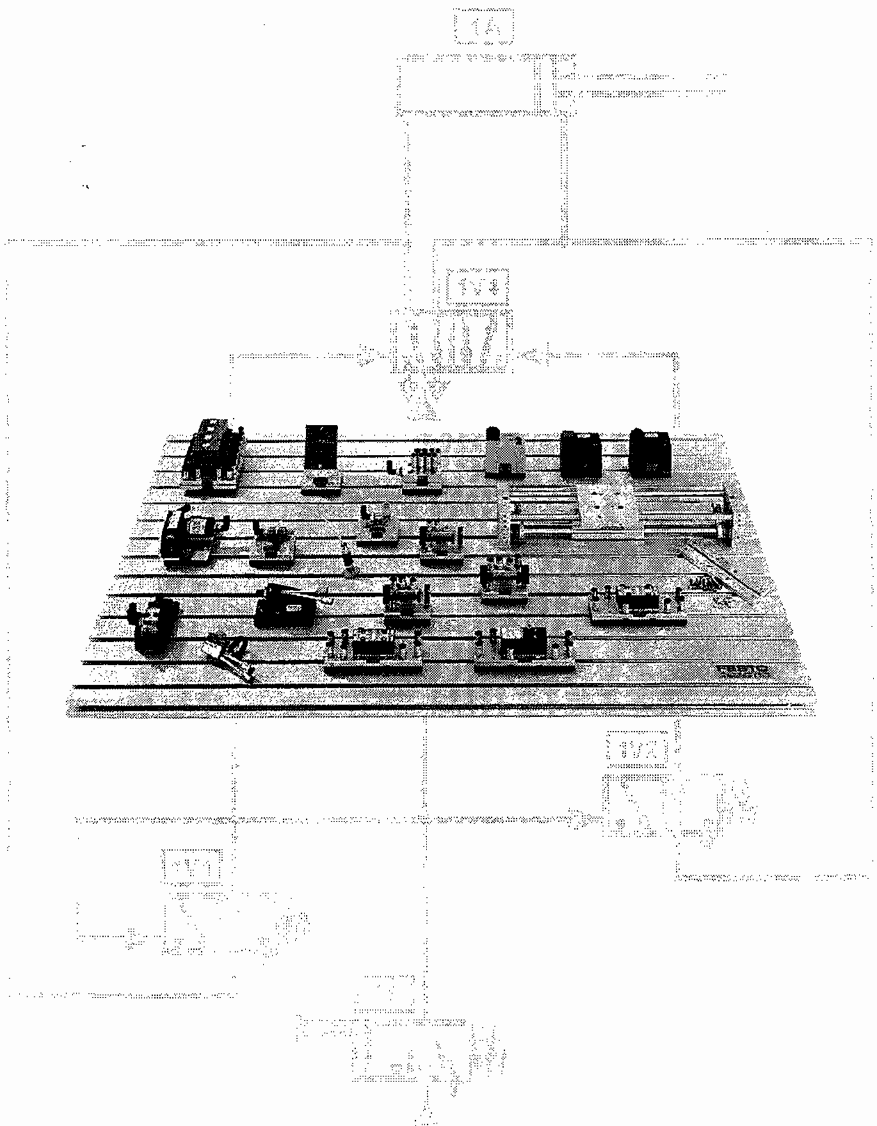
Learning System for Automation and Technology

Pneumatics

Workbook Advanced Level



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Authorised applications and liability

The Learning System for Automation and Technology has been developed and prepared exclusively for training in the field of automation and technology. The training organization and / or trainee shall ensure that the safety precautions described in the accompanying Technical documentation are fully observed.

Festo Didactic hereby excludes any liability for injury to trainees, to the training organization and / or to third parties occurring as a result of the use or application of the station outside of a pure training situation, unless caused by premeditation or gross negligence on the part of Festo Didactic.

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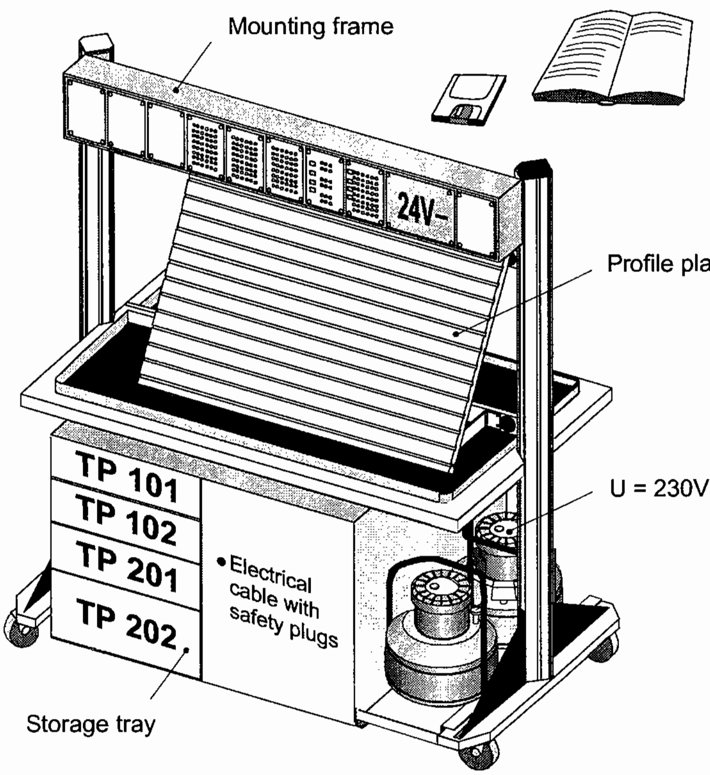
Preface

The Festo Didactic Learning System for Automation and Technology has been formulated according to various prerequisites and vocational requirements. It has been divided into the following categories of training packages:

- Basic packages which convey basic knowledge spanning a wide range of technologies
- Technology packages which deal with important subjects of open and closed-loop control technology
- Function packages to explain the basic functions of automated systems
- Application packages to facilitate practice-orientated vocational and further training

The technology packages deal with the technologies of pneumatics, electro-pneumatics, programmable logic controllers, automation with PC, hydraulics, electro-hydraulics, proportional hydraulics and handling technology.



The modular design of the Learning System permits applications beyond the scope of the individual packages. It is, for instance, possible to design PLC controlled systems with pneumatic, hydraulic and electrical actuators.

All training packages are based on an identical structure:

- Hardware
- Teachware
- Software
- Seminars

The hardware consists of industrial components and systems which have been adapted for didactic purposes.

The courseware has been designed in line with didactic methods and coordinated for use with the training hardware. The courseware comprises:

- Textbooks (with exercises and examples)
- Workbooks (with practical exercises, explanatory notes, solutions and data sheets)
- Transparencies and videos (to create a lively training environment)

The training and learning media is available in several languages, which has been designed for use in the classroom as well as for self-tuition.

The software sector serves as a basis for providing computer training program and programming software for programmable logic controllers.

A comprehensive range of seminars on the subject of the various technology packages completes our program of vocational and further training.

Latest information about the technology package pneumaticTP 102

New in Pneumatic 2000:

- Industrial components on the profile plate.
- Fostering of key qualifications:
  Technical competence, personal competence and social competence form professional competence.
- Training of team skills, willingness to co-operate, willingness to learn, independence and organisational skills.

Aim – **Professional competence**

Content

Part A	Course	Exercises
Part B	Fundamentals	Reference to the text book
Part C	Solutions	Function diagrams, circuits, descriptions of solutions and quipment lists
Part D	Appendix	Storage tray, mounting technology and datasheets

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Part A – Course

Part C – Solutions

Part D – Appendix

Introduction

This workbook forms part of the Learning System for Automation and Technology by Festo Didactic GmbH & Co. The system provides a solid framework for practically orientated vocational and further training. The Technology Package TP100 deals exclusively with pneumatic control systems.

Basic Level TP101 provides initial training in pneumatic control technology. Knowledge on the physical fundamentals of pneumatics as well as the function and application of pneumatic components is conveyed. The set of equipment enables the construction of simple pneumatic control systems.

The Advanced Level TP102 aims to provide further training in pneumatic control technology. The set of equipment can be used to build up extensive combination circuits with logic linking of the input and output signals as well as programmed control systems with stepper modules.

The training hardware of both equipment sets (TP101 and TP102) is required for the practical assembly of the documented controls. Four of the exercises in this collection call for the use of individual components (valves, cylinders, processors etc.), which are not part of equipment sets TP101 and TP102 or are not available in sufficient numbers (additional components).

A fixed workstation equipped with a Festo Didactic profile plate is an essential requirement for the practical assembly of the control systems described. The profile plate with 14 parallel T-grooves at intervals of 50 mm each.

For compressed air supply, a mobile, silenced compressor (230 V, maximum 8 bar = -800 kPa) may be used. A stationary compressed air supply is however more suitable as this reduces noise disturbance.

A grade of filtration of 0.04 mm (40 mm) ensures long-lasting, problem-free function of the pneumatic components. We recommend operation with unlubricated compressed air. Lubricated compressed air will not increase the service life of the components. If you are using pneumatic proximity switches, the compressed air supply must be unlubricated.

The maximum working pressure for a pneumatic linear drive is $p = 7$ bar (= 700 kPa). The maximum permissible pressure load for all other components in equipment sets TP101 and TP102 is a minimum of $p = 8$ bar (800 kPa).In some exercises, specific working pressures are to be set as detailed in the text.

Working pressure should be a maximum of $p = 6$ bar (600 kPa)

You will achieve maximum reliability of operation if the control system is run at a working pressure of $p = 5$ bar (500 kPa) with unlubricated air.

The theoretial fundamentals required for an understanding of this collection of exercises can be found in the textbook

- Fundamentals of Pneumatic Control Technology

In addition, there are data sheets for the individual components (cylinders, valves, measuring devices, etc.).

Each of the 20 exercises is divided into exercise sheets and solution sheets. The aim of the exercises is the development of the circuit (system circuit) and the practical assembly of the control system on the profile plate. It is not necessarily a meaningful exercise for all participants to draw up every circuit diagram. For the majority of participants it is more important to be able to construct a control system using a circuit diagram and to be able to carry out fault finding.

Notes on safety and operation

In the interest of your own safety you should observe the following:

- Pressurised air lines that become detached can cause accidents. Switch off pressure immediately.
- First connect all tubing and secure before switching on the compressed air.
- **Warning!**
  Cylinders may advance or retract as soon as the compressed air is switched on.
- Do not operate a roller lever valve manually during fault finding (use a tool).
- Observe general safety regulations (DIN 58126).
- Limit switches should be fixed so that they contact only the side of the trip cam (and not the front).
- Do not exceed the permissible working pressure (see data sheets).
- Pneumatic circuit construction: Use the silver-metallic plastic tubing of 4 mm external diameter to connect the components. The plastic tube is to be inserted fully into the CU-connector up to the stop; no tightening is necessary!
- Releasing the CU-quick push-pull connector: The tube can be released by depressing the clamping collet (black ring) (releasing whilst pressurised is not possible!)
- Switch off the air supply before disconnecting the circuit.
- The mounting plates for the components are equipped with mounting alternatives A to D

  Alternative A, Detent system
  Light, non-load bearing components (e.g. directional control valves). Simply clip the components into the groove on the profile plate; release is effected by pressing the blue lever.

  Alternative B, Rotational system
  Medium weight load-bearing components (e.g. actuators). These components are clamped on to the profile plate by means of T-head bolts. The components are clamped or released via the blue triple grip nut.

Alternative C, Screw-in system
For heavy load-bearing components, which are seldom removed from the profile plate (e.g. the on-off valve with filter regulator). These components are attached by means of cheese head screws and T-head nuts.

Alternative D, Plug-in system
Light non-load bearing components with locating pins (e.g. sequencer). These components are attached by means of a plug-in adapter.

- Observe the data given in the data sheets in Part D for individual components.

Stop watch

A stop watch is required in order to evaluate the assembled circuit. The stop watch is used:

- To adjust one-way flow control valves in order that the preset stroke time of a cylinder is reached,
- To set time delay valves,
- To be able to draw up displacement-time diagrams for the assembled circuits.

Technology package for pneumatics (TP100)

The technology package TP100 consists of a number of individual training aids as well as seminars. The subject matter of this package is purely pneumatic control systems. Individual components of the technology package TP100 may also form part of the content of other packages.

Practice and demonstration equipment

Important components of TP100:

- Fixed workstation with Festo Didactic profile plate
- Compressor (230 V, 0.55 kW, maximal 8 bar (800 kPa)
- Sets of equipment or individual components (e.g. cylinders, directional control valves, preselect counter, stepper modules, vacuum installation, logic elements, linear drive)
- Optional training aids (e.g. pneumatic proximity switches, visual displays, sequencer (Quickstepper), 5/3-way valve, pushing/pulling load)
- Practical models, complete laboratory installations

Books and teaching media

Textbooks	Basic level TP101 Fundamentals of pneumatic control technology Maintenance of pneumatic equipment and systems plus others
Workbook	Basic level TP101 Advanced level TP102
Optional courseware	Set of overhead transparencies and overhead projector Magnetic symbols, drawing template video cassettes CBT Fluid Studio Pneumatics WBT Fluid Studio Pneumatics Cut-away models (set 1 + 2) with storage cas Simulation software Fluid SIM Pneumatics

Seminars

P111	Introduction to pneumatics
P112	Instruction for vocational training in pneumatics
P121	Maintenance and fault finding in pneumatic control systems
P122	Design and assembly of pneumatic control systems
P124	Design and assembly of pneumatic control systems in vocational training

Dates and locations, as well as prices of courses, are listed in the current seminar brochure.

Further training aids can be found in our technical literature. The Learning System for Automation and Technology is continuously updated and expanded. The sets of overhead transparencies, video cassettes, as well as the textbooks and software, are available in several languages.

Training contents of basic level and advanced level

Basic level (TP101))

- Physical fundamentals of pneumatics
- Function and application of pneumatic components
- Designation and drawing of pneumatic symbols
- Representation of motion sequences and switching statuses
- Drawing pneumatic circuit diagrams in accordance with standards
- Direct and indirect stroke-dependent control systems
- Logic AND/OR functions of the input signals
- Time-dependent control systems with time delay valve
- Pressure-dependent control systems with pressure sequence valve
- Fault finding in simple pneumatic control systems
- Safety regulations

Advanced leve l(TP102)

- Function and application of pneumatic components
- Stroke-dependent control systems with different sensors
- Stroke-dependent control systems with preselect counter
- Control systems with start and setting-up conditions (AUTOMATIC/ MANUAL, SINGLE CYCLE/CONTINUOUS CYCLE, MANUAL STEP mode, STOP AT END OF CYCLE)
- Control systems with vacuum components
- Step diagram control systems/process-controlled sequence controls
- Program control systems with stepper
- Control systems with safety conditions (EMERGENCY-STOP/EMERGENCY-STOP reset)
- Program control systems with stepper modules (Quickstepper)
- Pneumatic counting, storing, adding
- Resetting of components (e.g. back pressure valve, proximity switch)
- Time-program control / Time-oriented sequential control
- Fault finding in extensive pneumatic control systems
- Safety regulations

Allocation of training aims and exercises (Table 1)

Training aim	Exercises 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Indirect actuation of actuators																				
– single-acting cylinder											•	•	•			•		•	•	•
– double-acting cylinder	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•
– linear drive						•	•			•		•		•	•	•	•	•		
– vacuum gen./ suction cup			•											•	•			•		
In the mid stroke range an actuator is to																				
– reverse									•						•	•				
– stop										•										
sequence control with																				
– individual valves	•	•	•	•																
– steps					•	•	•	•	•	•	•	•	•	•	•	•				
– sequencer																	•	•		
Logic control system																			•	•
Pneum. counting/calculating		•				•		•		•				•			•		•	•
Design of a control system with self-latching								•	•				•	•	•	•		•		
Realisation of stroke-dependent control systems with																				
– roller lever valve		•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•		
– roll.lev.valve w. idle return				•																
– back pressure valve				•			•				•	•	•				•	•		
– proximity switch				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		
Time-dep. control systems		•				•				•						•		•		
Pressure-dependent control systems with																				
– pressure sequence valve												•	•							
– pressure regulator			•								•									
– proximity switch			•											•	•			•		
Marginal conditions																				
– EMERGENCY-STOP							•		•				•	•	•					
– AUTOMATIC / MANUAL					•	•	•									•	•	•		
– RESET					•	•	•	•					•	•	•	•				
– SINGLE - / CONT. CYCLE			•		•											•		•		
– START	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•	•		
– STOP at END OF CYCLE							•	•								•		•		
– Program selection		•													•			•		

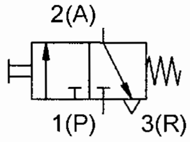
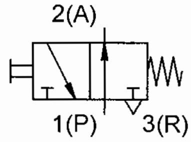
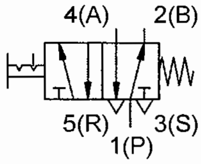
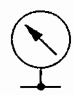
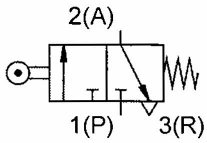
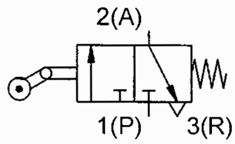
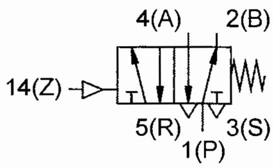
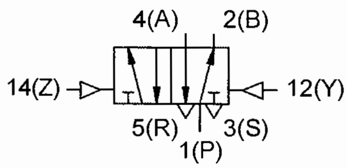
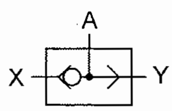
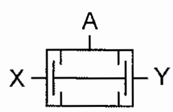
Set of equipment for basic level (TP101)

This set of equipment has been arranged for the purpose of basic training in pneumatic control technology. It contains all the components required for the teaching of the proposed syllabus and may be supplemented by other equipment as required. To construct fully operational control circuit, the assembly board and a power source are also necessary.

Equipment set for basic level (TP101) (Order No.: 080240)

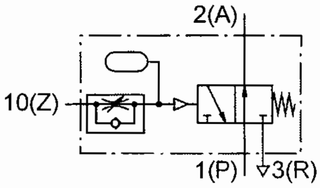
Description	*Order No.*	*Quantity*
Plastic tubing, 10 m, silver metallic	151496	2
3/2-way valve with push-button, normally closed	152860	3
3/2-way valve with push button, normally open	152861	1
5/2-way valve with selector switch	152862	1
Pressure gauge	152865	2
3/2-way roller lever valve, normally closed	152866	3
3/2-way roller lever valve with idle return, normally closed	152867	1
5/2-way pneumatic valve	152872	1
5/2-way double pilot valve	152873	3
Shuttle valve (OR)	152875	1
Dual-pressure valve (AND)	152876	1
Time delay valve, normally closed	152879	1
Quick exhaust valve	152880	1
One-way flow control valve	152881	2
Pressure sequence valve	152884	1
Single-acting cylinder	152887	1
Double-acting cylinder	152888	2
On-off valve with filter regulator	152894	1
Druckregelventil mit Manometer	152895	1
Manifold	152896	1
Connecting components	152898	1
Quick push-pull T-connector	153128	10

Symbols of the equipment set basic level

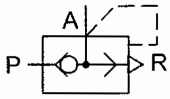
3/2-way valve with push button, normally closed 	3/2-way valve with push button, normally open 
5/2-way valve with selector switch 	Pressure gauge 
3/2-way roller lever valve, normally closed 	3/2-way roller lever valve with idle return, normally closed 
5/2-way pilot valve 	5/2-way double pilot valve 
Shuttle valve 	Dual-pressure valve 

Symbols of the equipment set basic level

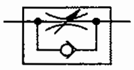
Time delay valve
normally closed



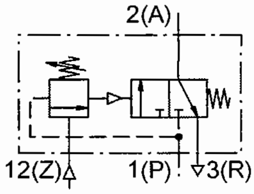
Quick exhaust valve



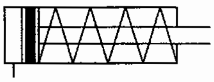
One-way flow control valve



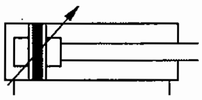
Pressure sequence valve



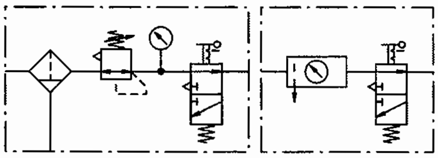
Single-acting cylinder



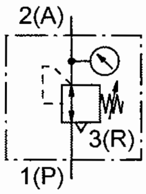
Double-acting cylinder



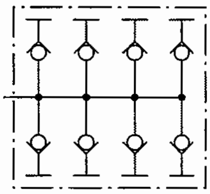
Service with on-off valve



Pressure regulator with pressure gauge



Manifold



Connecting components

2 Quick push-pull connectors M5
2 Quick push-pull connectors 1/8“
2 Angle quick push-pull connectors M5
2 Angle quick push-pull connectors 1/8“
6 Blanking plugs with sealing rings

Set of equipment for advanced level (TP102)

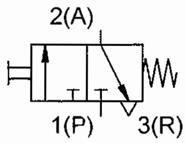
This equipment set for the advanced level is designed for further training in pneumatic control technology. The two equipment sets (TP101 and TP102) contain all the components required to achieve the specified training aim and may be extended as desired with the addition of other equipment sets from the Learning System for Automation and Technology.

Equipment set for advanced level (TP102) (Order No.: 080241)

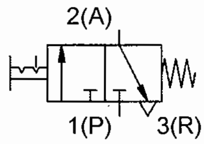
Description	*Order No*	*Quantity*
Adapter (for linear drive)	150519	1
Plastic tubing, 10 m, silver metallic	151496	2
3/2-way valve with push button, normally closed	152860	2
3/2-way valve with selector switch, normally closed	152863	1
3/2-way valve with mushroom actuator (red), normally closed	152864	1
3/2-way roller lever valve, normally closed	152866	1
Back pressure valve	152868	1
Pneumatic proximity switch	152870	3
3/2-way pneumatic valve, convertible	152871	2
5/2-way pneumatic valve	152872	2
5/2-way way double pilot valve	152873	3
Pneumatic preselect counter	152877	1
Time delay valve, normally open	152878	1
One-way flow control valve	152881	2
Shuttle valve, 3-fold (OR)	152882	2
Dual-pressure valve, 3-fold (AND)	152883	2
Stepper module, extension	152885	1
Stepper module	152886	1
Linear drive, pneumatic	152890	1
Vacuum generator/suction cup	152891	1
Adjustable vacuum actuator	152892	1
Connecting components	152898	1
Quick push-pull T-connector	153128	20

Symbols of the equipment set advanced level

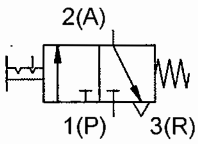
3/2-way valve with push button, normally closed



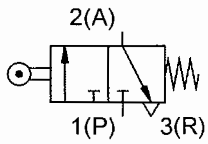
3/2-way valve with selector switch, normally closed



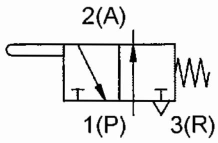
3/2-way valve with mushroom actuator (red), normally closed



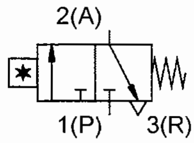
3/2-way roller lever valve, normally closed



Back pressure valve

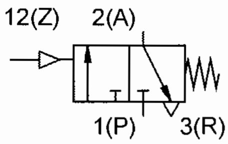


Pneumatic proximity switch

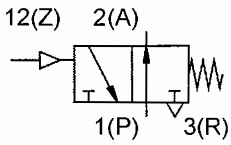


3/2-way pneumatic valve, convertible

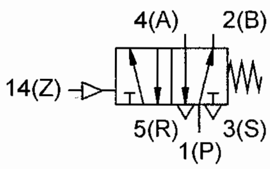
normally closed



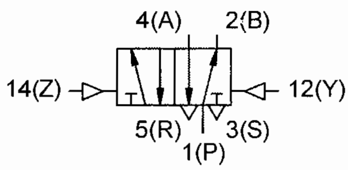
normally open



5/2-way pneumatic valve

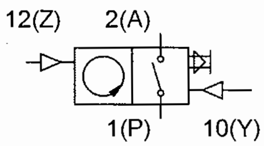


5/2-way double pilot valve

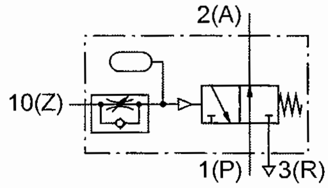


Symbols of the equipment set advanced level

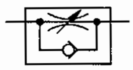
Pneumatic preselect counter



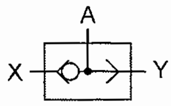
Time delay valve, normally open



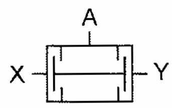
One-way flow control valve



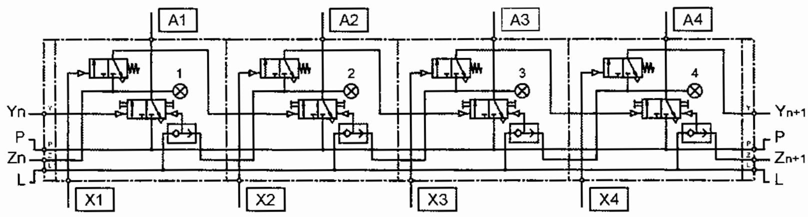
Shuttle valve, 3-fold



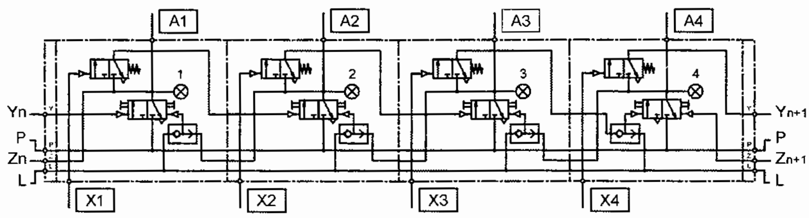
Dual-pressure valve, 3-fold



Stepper module, extension

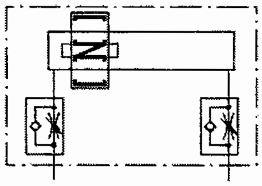


Stepper module

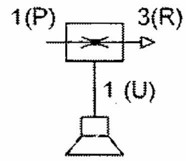


Symbols of the equipment set advanced level

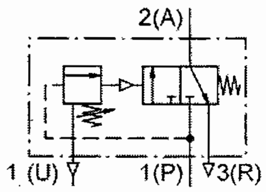
Linear drive, pneumatic



Vacuum generator / suction cup



Adjustable vacuum actuator



Connecting components

2 Quick push-pull T-connectors M5
2 Quick push-pull T-connectors 1/8"
2 Quick push-pull angle connectors M5
2 Quick push-pull angle connectors 1/8"
6 Blanking plugs with sealing rings

List of additional components for TP100

Description	*Order No.*
Memory module *	009708
Commander *	013985
Sequencer *	015609
5/3-way pneumatic valve, double piloted	152874
Pulling/pushing load	152889
Visual display	152893
Reservoir	152912

* These parts are equipped with barbed connectors.

Allocation of components and exercises (Table 2)

Description	Exercises 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
3/2-way valve with push button, normally closed	1	1		1		4	4	3	2	1	1	1	2	2	2	3	1	2	4	5
3/2-way valve with push button, normally open																		1		
5/2-way valve with selector switch		1				1	1	1							1	1		1		
3/2-way valve with selector switch, normally closed			1		1		1									1	1	1		
3/2-WV with mushroom actuator, red, normally closed									1				1	1	1			1		
Pressure gauge												1	1							
3/2-way roller lever valve, normaly closed		2	2	1	2	2	3	3	2		3	3	3	2	2	4	3	4		
3/2-way roller lerver valve with idle return, norm. closed				1																
Back pressure valve				1			1				1	1	1				1	1		
Pneumatic proximity switch				1	2	2	2	2	1	3	2	3	2	2	2	3	2	3		
3/2-way pneumatic valve, convertible	2	1	1			1	2	2	2	2	1		2		2		1	2		3
5/2-way pneumatic valve								1	3	1				3	2				3	3
5/2-way double pilot valve	2	3	2	2	2	2	5	2	1		4	4	5	4	3	5	3	5	3	8
Shuttle valve (OR)		1									1				1	1		1		
Dual pressure valve (AND)					1	1			1	1				1	1		1	1		
Pneumatic preselect counter		1						1						1			1			
Time delay valve, normally open		1				1				1										
Time delay valve, normally closed						1				1						1		1		

Description	Exercises 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Quick exhaust valve										1		1								
One-way flow control valve		4	2	4	4	2	2	4	2		1	2	2	2	2			4		
Shuttle valve 3-fold (OR)						2	2	1	2	2			2	2	2	2	2	2	2	2
Dual pressure valve 3-fold (AND)							1	2			1	1	1			1		2	2	2
Pressure sequence valve												1	1							
Stepper module, extension												1	1	1	1	1				
Stepper module					1	1	1	1	1	1	1	1	1	1	1	2				
Single-acting cylinder											1	1	1			2	1	1	1	1
Double-acting cylinder	1	2	1	2	2	1	2	2	1		2	2	2	1	1	2	2	2	2	2
Linear drive, pneumatic						1	1			1		1		1	1	1		1		
Vacuum generator / suction cup			1											1	1			1		
Adjustable vacuum actuator			1											1	1			1		
On-off valve with filter regulator	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pressure regulator with pressure gauge			1							1									1	
Manifold	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Additional components																2	2	3		
Number of components	8	19	14	15	17	24	30	26	21	18	21	26	30	28	29	34	23	43	20	28
Number of components used for the first time	6	6	4	3	2	3	1	0	1	1	1	3	0	0	0	2	2	1	0	0

Information useful to the instructor

■ Training aims

The *overall training aim* of this book of exercises is to teach the systematic design of circuit diagrams and the practical construction of the control system on the profile plate. The direct interaction of theory and practice ensures rapid progress.

The detailed *training aims are* listed in Table 1.

Specific training aims have been allocated to each exercise.

Naturally, in the course of practical work questions and problems arise which vary from one group of trainees to another. Nothing is more instructive than to spend time on these problems as they arise within the class.

As already mentioned in the introduction, owing to the increased complexity of the exercises, it is not always advisable to devote one's entire attention to the design of the circuit. What is essential is to focus on the practical didactic aspects. In exercise 13, for example, special attention is paid to "safety" aspects.

■ Training aim variations

The above *overall training aim* can be varied in many different ways. The design of control systems plays only a minor role in many people's jobs.

If, for example, the circuit diagram is supplied along with the problem definition, emphasis can be placed on the actual construction and commissioning of the control system.

Other possible training aims may be, for example, fault finding in fully assembled control systems or the modification of circuit diagrams or circuit documentation on the basis of a modified problem definition. In the theoretical part of the course, parts of the documentation for a control system (displacement-step diagram with/without signal lines, function diagram, function chart or other types of representation) may be drawn up using the circuit diagram.

If the displacement-step diagram with signal lines or the function chart are provided, the circuit diagram can be developed by a simplified method.

Another method of using the exercises can be to draw up the displacement-time diagram for each control system. Alternatively, a preset displacement-time diagram could be realised by adjusting components at the assembled control system.

The preparation of complete solution descriptions or of part of these based on the circuit documentation or the assembled control system also enables inter-disciplinary training (see also the aims of vocational training for workers in the engineering and electrical industries).

■ Time allocation

The time required for working through the problems set in the 20 exercises depends on the previous knowledge of the students:

- given previous training as a skilled machinist or electrician: approx. 160 hours,
- given that of a technician or engineer: up to 80 hours,

whereby the second group is to concentrate on the design of circuit diagram or of sections of circuit diagrams.

■ Component parts of the equipment set

The collection of exercises TP102 has been coordinated in line with didactic methods for use with the training hardware (equipment set for basic level TP101 and advanced level TP102.

For 16 of the 20 exercises, all you require are the components from these equipment sets.

Assembly of four of the exercises in this collection of exercises, however, requires additional components.

Exercise 16:	a stepper module and a memory module
Exercise 17:	a sequencer and a visual display
Exercise 18:	a sequencer, a visual display and a memory module
Exercise 20:	a 3/2-way pneumatic valve and two 5/2-way double pilot valves

Alternative solutions are shown for exercise 17. These alternative circuits cannot be constructed with just the components of the two equipment sets, but require additional components (optional components). In the same way, the problems set as part of the further developments will in part require additional components. Each exercise can be assembled on the profile plate.

Unlike TP101, TP102 on the whole dispenses with the “circuit design” diagram. Instead, the chapter “Notes on procedures” has been introduced, which deals in greater depth with simulation components, valves to be converted (e.g. creating a 3/2-way valve from a 5/2-way valve), inversion or negation of valves, resetting problems with sensors, control via pressure signals, pressure related problems (stick-slip effect), conditions during the assembly and commissioning of the circuits.

If certain notes recur in the next exercise, then the reason for this is based on the premise that a ‘newcomer’ often has difficulties with certain problems and that repetition is therefore helpful.

In the case of the more complex exercises it is useful, although not absolutely essential, to work with a second manifold. In this way, time consuming connecting up of quick push-pull distributors will be kept to a minimum.

We recommend that you use duplicates of circuit diagrams (copies) for the practical assembly of control systems on the profile plate. The trainee can then cross off any lines which have been connected up.

■ Designation of components

The components in the circuit diagrams are designated in accordance with ISO 1219-2. All components within a circuit have the same main code. Letters are assigned dependent on the component. If there are several components within a circuit, these are numbered consecutively. Pressure lines are identified with the designation P and are numbered separately.

Actuators:	1A, 2A1, 2A2, ...
Valves:	1V1, 1V2, 1V3, 2V1, 2V2, 3V1, ...
Switching valves:	1S1, 1S2, ...
Accessories:	0Z1, 0Z2, 1Z1, 1Z2, ...
Electrical sensors:	1B1, 1B2, ...
Pressure lines:	P1, P2, ...

Methodical structure of the exercises

Each of the 20 exercises is divided into exercise sheets and solution sheets. The problem description and positional sketch are as a rule based on a practical situation. In order to ensure optimum progress with training, automation problems from a practical background have been adapted for didactic purposes and the technical marginal conditions, e.g. (components list).

All 20 exercises in Part A are compiled in the same methodical way.

The exercise sheets are divided into:

– Subject,
– Title,
– Training aim,
– Problem

as well as

– Problem description
– Abbreviated notation
– Positional sketch

The proposed solutions in Part C cover at least four pages and are divided into:

– Notes on procedure,
– Components list,
– Circuit diagram,
– Displacement-step diagram
– Solution description

For exercises 1, 5 and 12 a “Circuit design” diagram has been added as in the Basic level.

Some of the exercises are extended with the addition of "Further development".

Alternative circuits provide a greater insight into purely pneumatic control technology.

In the case of exercises 12 to 18 extended circuit diagrams have been added which cover two DIN-A4 pages.

Part A – Course

Control systems without stepper module

Exercises 1 - 4

The first four exercises are a continuation of basic level TP 101 and basically act as an introduction. It is advisable to arrange all the equipment on the profile plate in accordance with the circuit diagram.

In this first group of exercises at the advanced level, the following components are used for the first time:

- Pneumatic preselect adder (exercise 2).
- Vacuum generator/suction cup, adjustable vacuum actuator (exercise 3).
- Pneumatic proximity switch (exercise 4).
- Back pressure valve (exercise 4).

The number of components used tends to increase from exercise to exercise. In order not to lose track of the components used, each valve should be identified from the outset (as per circuit diagram - e.g. 1.1, 2.4, etc.) using a soft pencil (HB) or stick-on labels (self-adhesive labels), so that these identifications may be removed from the components once they have been used. The designation should include the component number on the circuit diagram and where components are operated manually, the function achieved e.g. START, AUTOMATIC/ MANUAL.

1 Furnace door control

Discrete realisation of a binary reducer, indirect activation of a double-acting cylinder.

2 Vertical step feeder

Parallel movement by actuators working in a push-pull action, program selection via valve with detent, use of a pneumatic subtracting counter.

3 Separating of billets

Sequence control without signal overlap (special case), vacuum generation and sensing.

4 Drilling of wooden cubes

Sequence control with signal switch off, comparison of four different sensors (roller lever valve, roller lever valve with idle return, proximity sensor and back pressure valve).

Subject: *Pneumatics*

Title: **Furnace door control**

Training aim

- Realisation of a **binary reducer** (with individual valves).
- Indirect activation of a double-acting cylinder.
- Use of double solenoid valve (final control element, control element).
- Use of 3/2-way pneumatic valves with spring return.
- Converting a 3/2-way pneumatic valve(normally closed position /normally open position).
- Realisation of a control system without limit switch.

Exercise

- Draw the displacement-step diagram with signal lines in accordance with VDI 3260.
- Design and draw the system circuit diagram with the help of the problem description, positional sketch and displacement-step diagram.
- Compare your circuit diagram with the proposed solution.
- Remove the required components (valves, cylinders etc.) from the laboratory workstation.
- Assemble the selected components on to the Festo Didactic profile plate. It is a advisable to follow the layout of the components as shown in your circuit diagram.
- Connect up your circuit with the pressure supply switched off.
- Switch on the pressure supply and compare the operation sequence with the displacement diagram.
- Disconnect the control system and replace the components in the drawers of the laboratory workstation.
- Check that the equipment set is complete.

Exercise 1

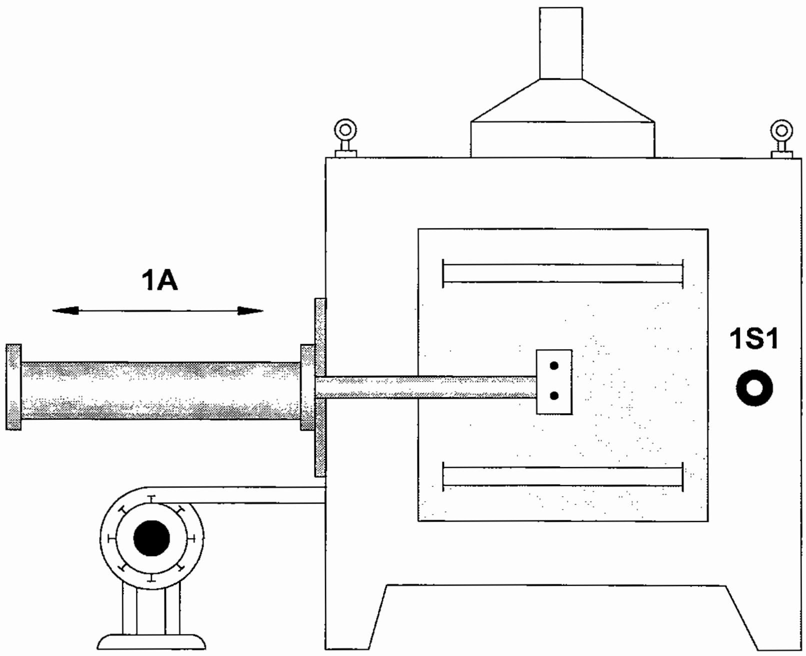
Problem description

The roller-mounted sliding metal door of the hardening furnace is moved by a pneumatic cylinder (A).

If the push-button valve (1S1) is actuated, the double-acting cylinder retracts and opens the sliding door. If this same valve is actuated a second time, the cylinder extends and closes the furnace door. Please construct the control system without using a limit switch.

Abbreviated notation **1A+ 1A–**

Fig. 1/1: Positional sketch



Subject

Pneumatics

Title

Vertical step feeder

Training aim

- Indirect activation of two identical double-acting cylinders via two final control elements.
- Use of a 5/2-way double solenoid valve as a control element.
- Realisation of a **parallel movement** by two actuators working in a push-pull action.
- Simulation of a mechanically driven guide by two cylinders.
- Exhaust air flow control of cylinders.
- Use of a normally open time-delay valve to switch off the start signal.
- **Program selection** via shuttle valve and aspring-returned 5/2-way valve with selector switch.
- Sensing of end positions using limit switches.
- Use of a pneumatic **preselect counter** to restrict the maximum number of cycles.

Exercise

- Draw the displacement-step diagram with signal lines.
- Design and draw the circuit diagram without pneumatic preselect counter for program I.
- Construct the control system without pneumatic preselect counter for program I.
- Set the four one-way flow control valves (simulation of the mechanical driven guide).
- Extend the circuit diagram in accordance with the problem description (with preselect counter, program I and II).
- Construct the control system in accordance with the problem description (with preselect counter, program I and II).
- Carry out a function check.
- Compare your own solution with the proposed solution.
- Disconnect, sort, check that the equipment set is complete.

Problem description

Two identical double-acting cylinders (1A) and (1B) move a suspended basket stepwise in a push-pull action via two cords and a rocking beam. The exhaust air of the two cylinders is throttled during both advance and return strokes. A roller lever valve is located in each of the retracted end positions.

Program I:
If a valve with push-button actuator (0S2) is detented, the two cylinders carry out a double stroke simultaneously and loft the basket by twice the length of the stroke. A new start signal may only become effective once this START button has been released. This is achieved using a time delay valve. The maximum possible number of double strokes is limited to ten by a counter.

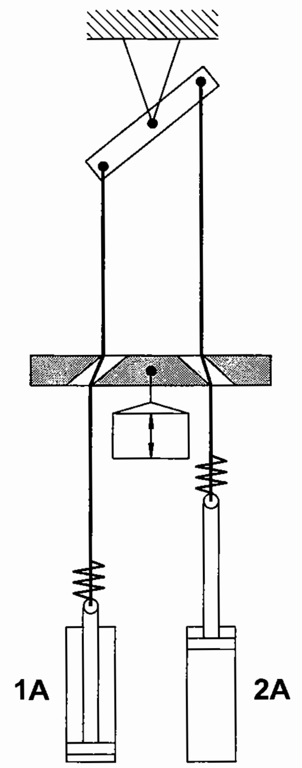
Program II:
If a valve with selector switch is actuated, only cylinder (1A) extends. The slackened cords cause the suspended basket to slip down. Valve actuation via the detented selector switch simultaneously resets the counter.

Abbreviated notation

Program I: **1A+** **1A–**
2A– **2A+**
max. 10 double strokes

Program II: **1A+** **1A–**

Fig. 2/1: Positional sketch



Subject
Pneumatics

Title
Separating of billets

Training aim

- Realisation of a sequence control without signal overlap (special).
- Activation of a double-acting cylinder and a vacuum generator with suction cup via two final control elements (5/2- or 3/2-double pilot valve).
- Connection and adjustment of the adjustable vacuum actuator.
- Setting the required suction performance via the supply pressure.
- Conversion of valves.

Exercise

- Draw the displacement-step diagram.
- Enter the signal elements on the displacement-step diagram
- Design and draw the circuit diagram.
- Construct the control system.
- Check the functioning of all valves to ensure that they are switching correctly. (How can the contact of the billet with the suction cup be simulated?).
- Compare your solution with the proposed solution.
- Disconnect, sort and check that the equipment set is complete.

Problem description

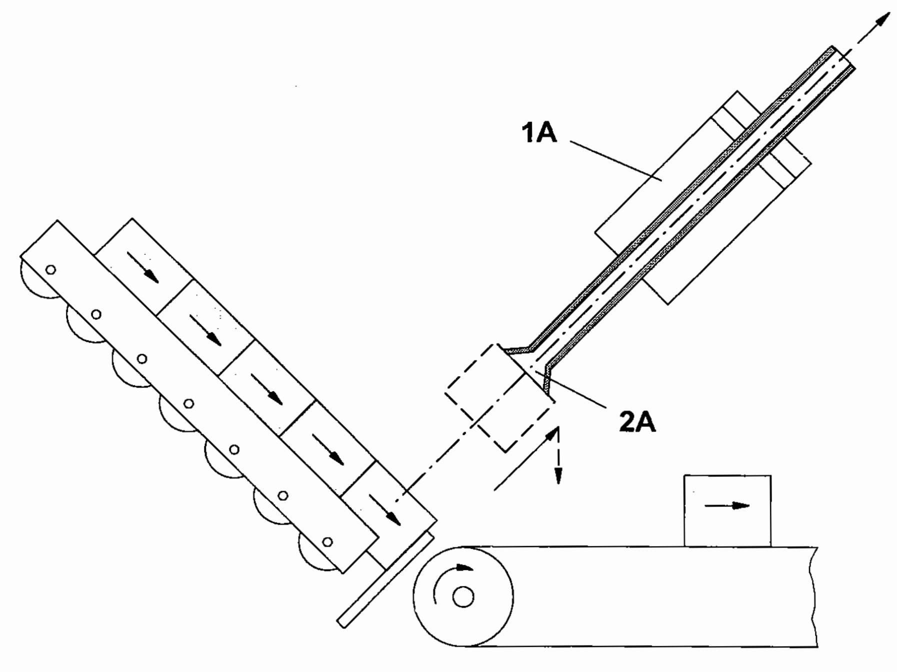
Billets are transferred from a roller feeder set at an angle to a conveyor belt. Transfer is effected via a double-acting cylinder (1A) with hollow piston rod, attached suction cup (2A) and a vacuum generator.

When a valve with selector switch is actuated, the cylinder extends with exhaust air throttled. A roller lever valve is actuated in the forward end position. This causes the vacuum generator to be switched on. When the vacuum has been generated, the return stroke of the cylinder is effected via an adjustable vacuum actuator and the billet is lifted. A roller lever valve in the retracted end position causes the vacuum generator to be switched off; the workpiece falls on to conveyor belt.

If the valve with selector switch is reset, the continuous motion sequence ceases at the end of the cycle. The supply pressure of the vacuum generator is set by a pressure regulator.

Abbreviated notation **1A+ 2A+ 1A– 2A–**

Fig. 3/1: Positional sketch



Subject

Pneumatics

Title

Drilling of wooden cubes

Training aim

- Indirect activation of two actuators each with a final control element.
- Development and construction of a control system with **signal overlap**.
- Use and **comparison** of four **different sensors**.
  - – Roller lever valve (start interlock)
  - – Roller lever valve with idle return (signal overlap)
  - – Back pressure valve (with poppet control)
  - – Magnetically actuated proximity sensor

Exercise

- Draw up the displacement-step diagram with signal lines.
- Develop and draw the circuit diagram.
- Compare your solution with the proposed solution.
- Construct the control system and adjust the signal elements.
- Activate the control system and check to ensure that the cycle is correct.
- Disconnect, sort and check that the equipment set is complete.

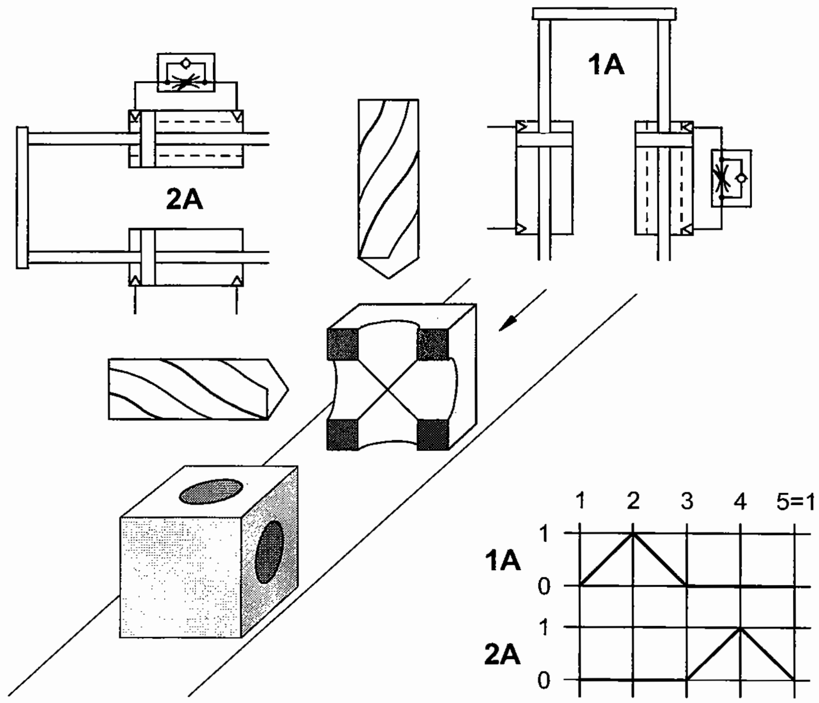
Problem description

Wooden cubes are drilled horizontally and vertically by two pneumatically driven feed units with hydraulic cushioning cylinders. The drilling axes intersect. The start is effected via a push-button valve

The vertically operating feed unit (1A) reports its position directly to the final control element via a roller lever valve with idle return and a back pressure valve. The horizontally operating unit (2A) is equipped with a roller lever valve in the retracted end position and with a contactless pneumatic proximity switch on the cylinder barrel.

Abbreviated notation **1A+ 1A– 2A+ 2A–**

Fig. 4/1: Positional sketch with displacement-step diagram



Exercises 5 - 11

Control systems using one stepper module

The stepper module is the central theme in this group of exercises. Marginal conditions such as EMERGENCY-STOP, RESET and cycle repetitions, are enabled by an additional command module.

When factors determining reliability, e.g. response to influencing characteristics, occur, they are discussed.

In addition, operation with the “black-box” is introduced. After a brief phase of familiarisation, it becomes clear that it is considerably simpler to understand the circuits if you assume that the black box deals with incoming and outgoing signals only and ignore internal functions.

Like all other valves, the stepper module is shown by a symbol on the circuit diagram. The complete symbol is used in the circuit diagram for Exercise 5. In all subsequent diagrams a simplified symbol is used. The sequencer is regarded as a “black-box”. The mechanism is not of interest. Only the outward-going functions need to be considered.

5 Filling of medicine bottles

Basic stepper module with continuous cycle.

6 Feeding device for electro-plating bath

Stepper control with the functions: AUTOMATIC/MANUAL, START and RESET; linear drive.

7 Feed unit

Stepper control with the functions: EMERGENCY-STOP/EMERGENCY-STOP unlatching, AUTOMATIC/MANUAL, START and STOP at END OF CYCLE; linear drive.

8 Packing of spark plugs

Stepper control with self-latching circuit and the functions: AUTOMATIC/MANUAL, START, STOP at END OF CYCLE, RESET and magazine interrogation as well as step repetition via preselect counter.

9 Sealing device

Stepper controller with protected control air and the function: EMERGENCY-STOP, START and RESET; Reversal of the actuator in the partial stroke area. In case of EMERGENCY-STOP, the cylinder travels into the retracted end position. If it is in an end position, it remains there.

10 Hardening of material samples

Stepper control with START function; stopping of the actuator in the partial stroke area (positioning).

11 Bending device

Control with response to set point changes and sequence control of stepper design, START function.

Subject: *Pneumatics*

Title: ***Filling of medicine bottles***

Training aim

- Indirect activation of two double-acting cylinders.
- Realisation of a **basic sequence control** with continuous cycle.
- Use and adjustment of pneumatic proximity switches (actuated or unactuated in the initial position).
- Simplified representation of stepper module as a "black-box".

Exercise

- Start by working with the stepper module (without actuators and sensors). Connect up the ports: Zn to Zn+1, Yn to Yn+1 as well as A1 to X1, A2 to X2, A3 to X3, A4 to X4 and connect P to the compressed air supply (port L remains unconnected). The sequencer now runs through the cycle automatically.
- What is the result of a break in the tubing, A1-X1, ... A4-X4 or Zn-Zn+1 and Yn-Yn+1?
- Explain in writing the method of operation of the stepper modules (see also Textbook).
- Draw the displacement-step diagram with signal lines.
- Develop and draw the circuit diagram.
- Construct the control system.
- Adjust the pneumatic proximity switches.
- Disconnect, sort and check that the equipment set is complete.

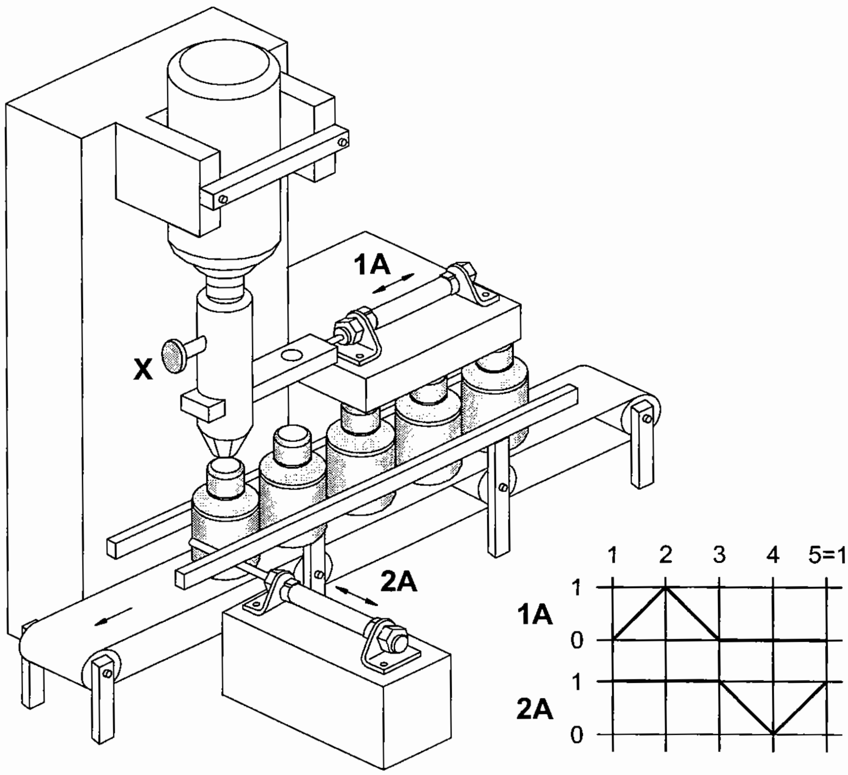
Problem description

Medicine bottles are pushed against the extended piston rod of the separating cylinder (2A) by a continuously running conveyor belt. The dispensing cylinder (1A) closes the feed container in the retracted position.

If a push-button valve is actuated, the dispensing cylinder (1A) extends with exhaust air throttled and then retracts again. Both cylinder end positions are sensed by roller lever valves. The filling capacity is adjusted with screw (X). Then, the separating cylinder (2A) retracts and extends again immediately with exhaust air throttled. The flow control is to be adjusted in such a way that a new empty medicine bottle is located under the filling valve. Two proximity switches signal the cylinder position to the sequencer. If the valve with selector switch is reset, the motion sequence ends at the end of the cycle.

Abbreviated notation **1A + 1A – 2A – 2A +**

Fig. 5/1: Positional sketch with displacement-step diagram



Subject

Pneumatics

Title

Feeding device for electro-plating bath

Training aim

- Indirect activation of two actuators by two final control elements.
- Use of a pneumatic linear drive.
- Realisation of a **sequence control system with the functions** AUTOMATIC/MANUAL, START and RESET.
- Realisation of the OR-connection by acknowledgement signals.
- Use and adjustment of pneumatic proximity sensors.
- Setting and adjustment of time delays (signal variation).
- Termination of delay times by push button via an OR connection.

Exercise

- Draw the displacement-step diagram with signal lines.
- Design and draw a simplified circuit diagram without taking into account the marginal conditions.
- Construct the control and adjust the signal elements.
- Extend the circuit diagram in accordance with the problem description.
- Construct the control on the profile plate.
- Adjust the time elements with the aid of a stop watch.
- Activate the control and check all functions.
- Compare your solution with the proposed solution.
- Prepare a displacement-step diagram for the control.
- Disconnect, sort and check that the equipment set is complete.

Problem description

If a valve with push button (0S2) is actuated, a horizontally installed rodless linear drive (1A) with exhaust air throttled on both sides and proximity sensors in the end positions (1S1 and 1S2) transfers the wire basket to the right beneath the suction hood covering the bath. Once the double-acting immersing cylinder (2A) has extended, the basket remains in the bath for t_1 = 5 seconds. When the basket is lifted out again, it remains stationary for t_2 = 4 seconds to drain off before the horizontal cylinder once more approaches its lefthand end position.

The exhaust from the movement of the immersing cylinder is throttled on both sides; roller lever valves (2S1) and (2S2) are mounted at the end positions.

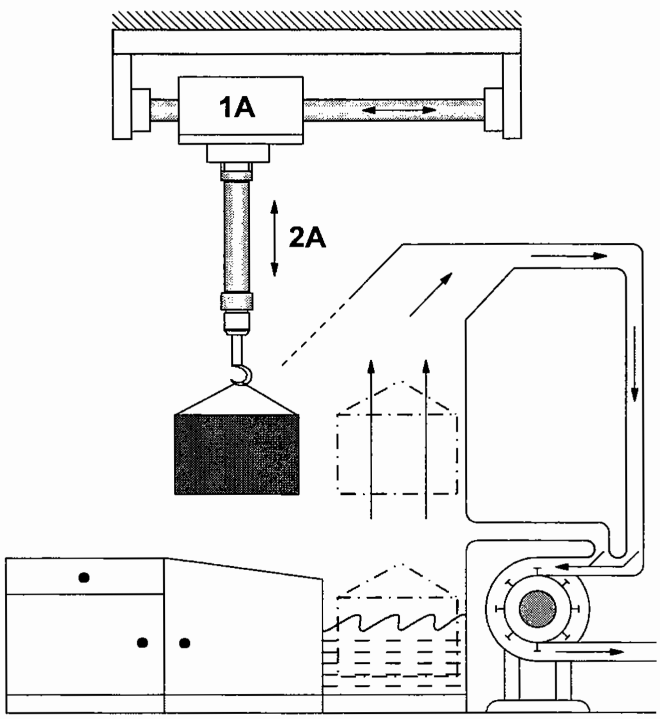
Marginal conditions

If a 5/2-way valve with selector switch (0S1) is switched from AUTOMATIC to MANUAL, the actuating section and the sequencer can be reset by a push-button valve (0S3).

Actuation of a third push-button valve (0S4) causes the bath immersion time t_1 to be terminated and the immersing cylinder (2A) returns to the retracted end position. Actuation of a fourth valve push-button valve (0S5) concludes the draining time t_2.Thehorizontal cylinder (1A) travels to its initial position.

Abbreviated notation **1A+ 2A+ 2A– 1A–**

Fig. 6/1: Positional sketch



Subject: *Pneumatics*

Title: ***Feed unit***

Training aim

- Recognising the motion sequence of the feed unit principle.
- Indirect actuation of three actuators with double solenoid valves.
- Realisation of a sequence control with the functions EMERGENCY STOP/ EMERGENCY STOP unlatching, AUTOMATIC/MANUAL, START, STOP at END OF CYCLE and RESET.
- Realisation of AND connection for the acknowledgement signals.
- Use and adjustment of three different sensors.

Exercise

- Draw up the displacement-step diagram with signal lines.
- Design and draw the circuit diagram with themarginal conditions.
- Construct the control and set the signal elements.
- Extend the circuit diagram in accordance with the problem description.
- Assemble your control system on the profile plate
- Activate the control and check all functions.
- Compare your solution with the proposed solution.
- Disconnect, sort and check that the equipment set is complete.

Problem description

A plastic strip is fed to a screen printing machine by an indexing feed unit.

The cycle starts with the simultaneous extension of the feed grippers (1A) and the retraction of the holding grippers (2A). Once the feed cylinder (3A) has extended, the two gripper cylinders travel simultaneously into the opposing end positions. The cycle is concluded with the return stroke of the feed cylinder (3A). The exhaust air is throttled during the return strokes of both grippers.

In the retracted end position, the feed gripper (double-acting cylinder) actuates a roller lever valve. The forward end position is acknowledged by a back pressure valve. The two end positions of the holding grippers (double-acting cylinders) are acknowledged by roller lever valves. A linear drive is used as a feed cylinder, whose end positions are sensed by means of proximity sensors.

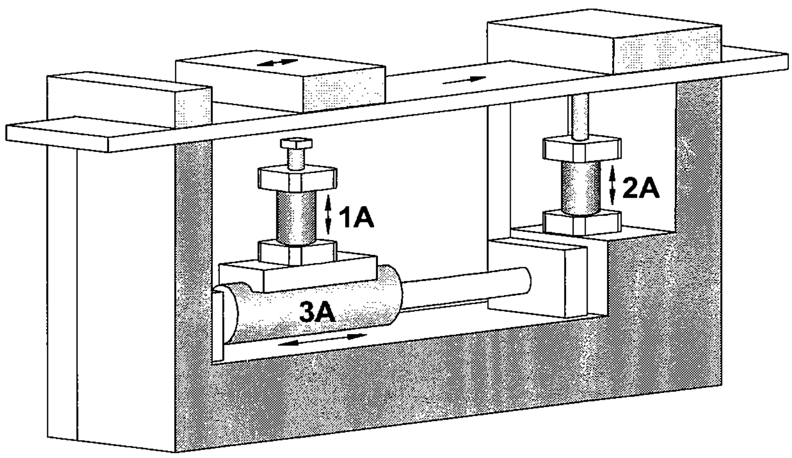
Marginal conditions

Selection can be made between MANUAL and AUTOMATIC mode by a valve with selector switch. In AUTOMATIC mode, two push-button valves are pressurised (START, STOP at END OF CYCLE), which influence a memory. Two further valves with mushroom actuator or push button (EMERGENCY-STOP, EMERGENCY-STOP unlatching) also act on a memory. When EMERGENCY-STOP is actuated, the holding gripper clamps and the feed cylinder are exhausted on both sides. Before unlatching of EMERGENCY-STOP, the sequencer and actuators are set via a fifth valve.

Abbreviated notation

1A+	**3A+**	**1A–**	**3A–**
2A–		**2A+**	

Fig. 7/1: Positional sketch



Subject

Pneumatics

Title

Packing of spark plugs

Training aim

- Indirect activation of two cylinders by two final control elements.
- Use of roller lever valves and pneumatic proximity switches.
- Realisation of a **sequence control system with an idle step** (3 steps).
- Variable step repetition within a motion sequence by means of **a pre-select counter**.
- Development of an **input circuit with self-latching** and the functions AUTOMATIC/MANUAL, START, STOP at END OF CYCLE AND RESET.
- Use of a sensor for magazine monitoring.

Exercise

- Draw the displacement-step diagram with signal lines.
- Design and draw the simplified circuit diagram without taking into consideration the marginal conditions (using a START button).
- Construct the control system and adjust the signal generators.
- Extend the circuit diagram in accordance with the problem description
- Construct your control system on the profile plate.
- Check the control system for all functions and systematically test all the marginal conditions.
- Compare your solution with the proposed solution.
- Disconnect, sort and check that the equipment set is complete.

Problem description

Two double-acting cylinders operate two magazines. Four spark plugs at a time are fed from the lefthand magazine to a box which is open at the top and has a central partition. When the righthand gravity feed magazine cylinder (1A) with exhaust air throttled on both sides extends, a box is pushed out of the magazine to the left. Then, the horizontal magazine cylinder (2A) extends for four double strokes, likewise with exhaust air throttled on both sides and allocates the spark plugs. The cycle is completed with the retraction of the gravity feed magazine cylinder (1A). The end positions of the gravity feed magazine (1A) are detected by roller lever valves. Two proximity switches monitor the end positions of the horizontal magazine cylinder (2A).

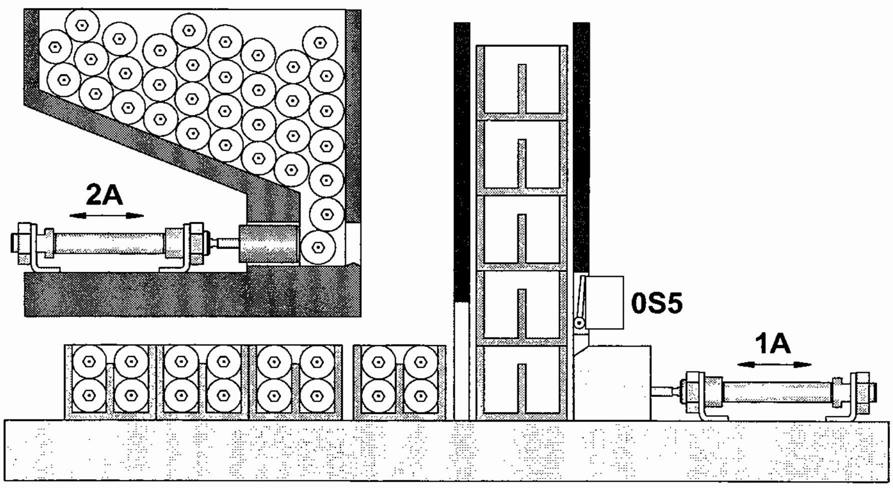
Marginal conditions

A self-holding latching circuit is created by actuating the START button. The control system runs in continuous cycle. When the STOP button is actuated at the END OF THE CYCLE, the self-holding circuit is broken and the stored continuous start signal cancelled. Self-holding is also interrupted or else cannot be established when the roller lever valve in the gravity feed magazine is not actuated. This is the case when there are no spark plug boxes in the shaft. In AUTOMATIC mode, the self-holding circuit and sequencer are supplied with compressed air. If the control is switched to MANUAL via a 5/2-way valve with selector switch, the RESET button is pressurised. The actuation of this causes both cylinders to extend and the sequencer assumes the initial position. It is not possible to start when boxes are not present since roller lever valve (0S5) will be closed.

Abbreviated notation

1A+ $\underbrace{\textbf{2A+}\quad\textbf{2A–}}_{\textbf{4 times}}$ 1A–

Fig. 8/1: Positional sketch



Subject

Pneumatics

Title

Sealing device

Training aim

- Indirect activation of a cylinder.
- Activation of the final control element in two steps via a shuttle valve (double stroke of the actuator).
- Use of a proximity switch in the mid-stroke area to achieve the **reversal of movement of the actuator**.
- Development of an input circuit for **a stepper control with protected control air** and the functions START, EMERGENCY-STOP and RESET.

Exercise

- Draw the displacement-step diagram with signal lines.
- Design and draw the simplified circuit diagram without taking into consideration the marginal conditions.
- Construct the control system and set the proximity switches.
- Extend the circuit diagram to incorporate the marginal conditions.
- Assemble the control on the profile plate.
- Check the control system to ensure that it functions correctly, paying particular attention to the EMERGENCY-STOP situation for each step.
- Compare your solution with the proposed solution.
- Disconnect, sort and check that the equipment set is complete.

Problem description

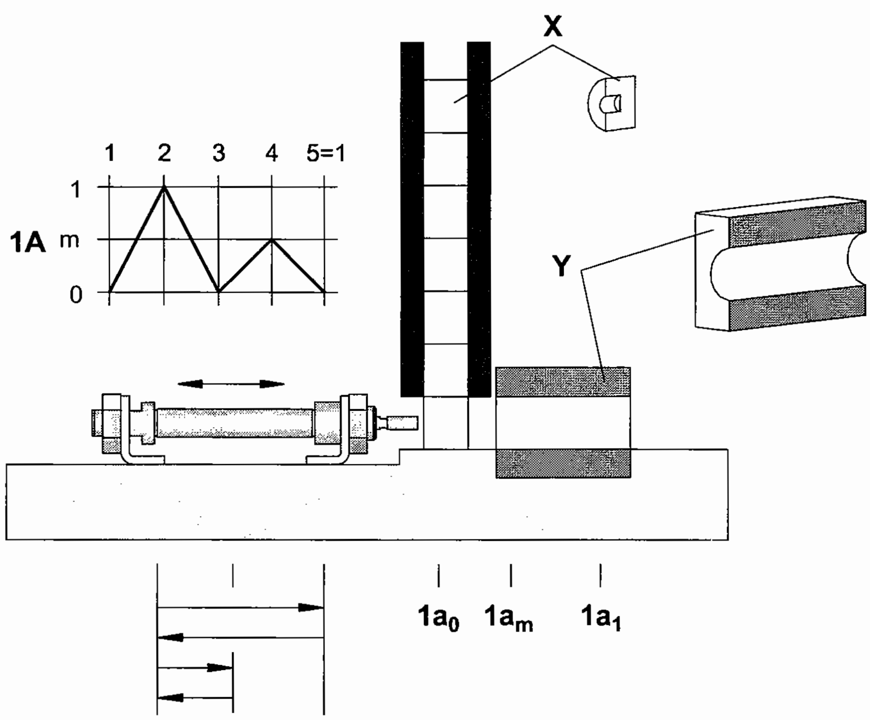
Guide bushes (Y) with lapped through-hole are sealed on both sides by a plastic plug (X). The guide bushes are inserted by hand; the plugs are fed via a gravity feed magazine.

The START signal causes the piston rod of the double-acting cylinder (1A) with exhaust air throttled on both sides, to fully extend. A plug is pressed through the hole and seals the righthand opening of the bush. When the piston rod has retracted a second plug drops down. Then, the piston rod extends for half a stroke and retracts again immediately. This movement seals the lefthand side of the bush (Y). The cylinder end positions are monitored by roller lever valves; reversal in the partial stroke area activates a proximity switch

Marginal conditions

The control air supply for the sequencer is protected by a self-holding circuit. A single cycle is introduced by actuating the START button. Actuation of the EMERGENCY STOP detent interrupts the self-latching circuit; if the cylinder is in motion, it travels into its retracted end position, if it is in an end position, it stays there. If the RESET button is pressed, both the actuator and the processor revert to their initial position.

Fig. 9/1: Positional sketch with displacement-step diagram



Pneumatics — *Subject*

Hardening of material samples — *Title*

Training aim

- Indirect activation of a pneumatic linear drive by two normally closed 3/2-way pneumatic valves.
- **Stopping the actuator in the mid stroke area** (positioning) by applying pressure to both sides (pre-pressurising).
- Adjustment of proximity switches in the end positions and in the mid stroke area.
- Combined use of quick exhaust valve and pressure regulator with pressure gauge.
- Inversion of a timer signal.
- Variation of the end position cushioning.

Exercise

- Draw the displacement-step diagram with signal lines (qualitative).
- Draw in the inversed timer signals and compare your solution with the circuit diagram.
- Design the circuit diagram.
- Compare your solution with the proposed solution.
- Construct the control system in accordance with the circuit diagram.
- Observe the difference prepressurising makes to the cycle; remove the components (1V5), (1V8), (1V4) and (1V6).
- Adjust the timers and one-way flow control valves so that an identical mid position is reached in the forward and return strokes and the prescribed stopping times are attained.
- Harmonise the two operating pressure in order to achieve the fastest possible movement.
- Plot the displacement-step diagram for your control (quantitative).
- Vary the setting of the end position cushioning for the linear drive in the right and lefthand end positions (using a small screwdriver).

Problem description

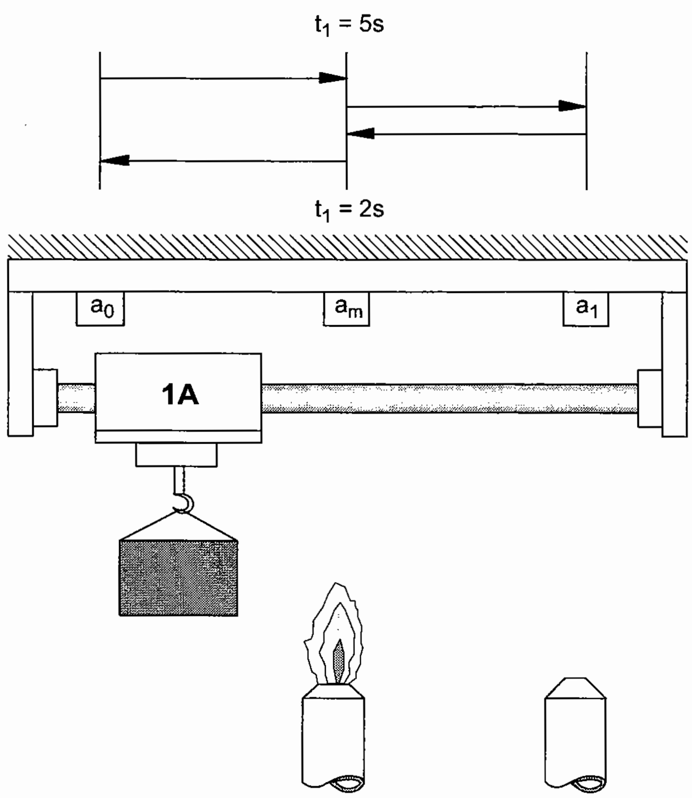
Trial materials from various melting processes are subjected to a reproducible heat treatment. The alloyed steel workpiece samples are annealed, quenched and tempered.

The sample is placed in the wire basket and the START button is pressed. The linear drive (1A) travels from the lefthand end position ($1a_0$) to the mid-position ($1a_m$). After an annealing time of t_1 = 5 seconds, the righthand end position ($1a_1$) is approached and the sample is plunged in a moderate oil or water bath. Before the linear drive once more assumes the normal position, it remains in the mid-position for t_2 = 2 seconds for tempering.

The position of the actuator is sensed by three proximity switches. The two pressure chambers of the linear actuator are continuously pressurised with a pressure of p = 4 bar (400 kPa), with exhaust air throttled on both sides.

The position of the actuator is sensed by three proximity switches. The actuator is activated by two spring-returned 3/2-way valves. These are actuated with a pressure of p = 6 bar (600 kPa).

Fig. 10/1: Positional sketch



Subject

Pneumatics

Title

Bending device

Training aim

- Indirect activation of two double-acting cylinders by two 5/2-way double pilot valves.
- Indirect activation of a single-acting cylinder by a spring returned 3/2-way double pilot valve.
- Use of a one-way flow control valve for **supply air restriction**.
- Realisation of a **control with response to set point changes** in conjunction with a sequence control of stepper design.
- Use and adjustment of three different sensor types.

Exercise

- Draw the displacement-step diagram with signal lines.
- Develop and draw the circuit diagram for the sequence control system (only cylinders (2A) and (3A) with START button).
- Construct the partial control and adjust the proximity switches.
- Extend the circuit diagram in accordance with the problem description. Why does clamping cylinder (1A) have response to set point changes?
- Construct your control on the assembly board.
- Check your control to ensure that it functions correctly.
- Compare your solution with the proposed solution.
- Disconnect, sort and check that the equipment set is complete.

Problem description

Strips of metal (X) are bent using a bending tool. The strip is inserted by hand. Once the START button has been pressed, cylinder (1A) clamps the workpiece. Cylinder (2A) bends the part by 90° and retracts again immediately. Cylinder (3A) finishes the bending process. Next, cylinders (1A) and (3A) retract simultaneously. The formed workpiece is removed by hand.

The single-acting clamping cylinder (1A) has its supply air throttled and is activated by a spring-returned 3/2-way final control valve, cylinders (2A) and (3A) on the other hand by a 5/2-way double pilot valve and a stepper module. The end positions of the double-acting bending cylinder (3A) are sensed by two proximity switches. A back pressure valve checks the forward end position of the single-acting clamping cylinder (1A). The other three end positions are monitored by roller lever valves.

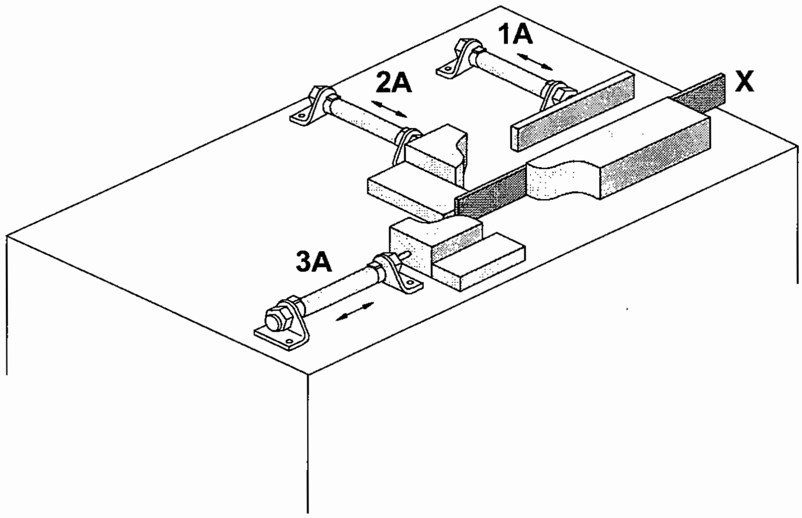
Marginal conditions

The movement of the clamping cylinder (1A) should be guided. This means that the program control is started on reaching the forward end position. If the START button is released before the cylinder has reached the forward end position, it returns to its initial position.

Abbreviated notation

1A+ 2A+ 2A– 3A+ 1A–
3A–

Fig. 11/1: Positional sketch



Exercises 12 - 15

Control systems using two stepper modules

In this group of exercises, components which are already familiar (valves, cylinders, etc) are combined to form extensive control systems. The marginal conditions in particular, gain greater importance within a circuit. All control systems can be effected using the components from the equipment sets TP101 (basic level) and TP102 (advanced level).

If the students involved in the course are at an advanced level, it is a good idea to set aside a complete training day for each circuit. If this is done, it should be possible for well-prepared students to develop an entire control system on their own.

Once again, the stepper modules are the central theme of this block of exercises. The extension stepper module is used for the first time here. It can only be used as an extension to the previously used stepper module. If the two assemblies are switched in sequence, a control system with 2 x 4 steps = 8 steps is possible.

Exercise 12 is a sequence control with seven steps (4 actuators). The connection of the two stepper modules is explained. For this reason, both a circuit diagram and a circuit design are given in the solution.

In exercise 13, the two stepper modules are combined for the second time. The differences between this exercise and exercise 12 are

- Input circuit with self-latching circuit.
- Step repetition.
- EMERGENCY-STOP circuit for actuator and processor.

In exercise 14, cycle repetitions are limited by a counter for the first time (the pneumatic preselect counter is also used in exercises 2 and 8 as well as in exercise 17).

In exercises 14 and 15, two circuit designs for vacuum components are compared (vacuum suction generator/suction cup, adjustable vacuum actuator; vacuum components are also used in exercises 3 and 18).

With optimal tubing and setting of components, cycle times of considerably less than t = 2 seconds are achieved.

A choice is made between programs I and II in exercise 15 by reversing a 3/2-way valve (program selection is also possible in exercises 2 and 18).

12 Cleaning plant for housing parts

Basic stepper sequencer with two stepper modules,START function, pressure and end position sensing, step.

13 Flat grinding machine

Stepper controller with protected control air (self-latching circuit) and the functions: EMERGENCY-STOP, START and RESET, combined pressure and end position sensing. If the EMERGENCY-STOP is actuated, cylinder 2A is exhausted on both sides irrespective of its position.

14 Stacking device

Stepper controller with self-latching circuit and the functions: EMERGENCY-STOP, START and RESET. Vacuum build up and decay is sensed and acts as a step-enabling condition. The number of cycle repetitions is limited by a counter.

15 Separation of packages of varying height

Stepper controller with self-latching circuit and the functions: EMERGENCY-STOP, START, RESET. Select program I or II by switching a detented valve. Vacuum build-up and decay is sensed and acts as a step-enabling condition.

Subject

Pneumatics

Title

Cleaning plant for housing parts

Training aim

- Indirect activation of four actuators with four final control elements.
- Realisation of **a basic stepper control with two stepper module units** and single cycle.
- Use and adjustment of three types of sensors.
- Installation of a pressure sequence valve and a quick exhaust valve.
- Realisation of an AND-connection of acknowledgement signals for **pressure and end position sensing**.

Exercise

- First of all work only with the two stepper modules (without actuators and sensors). Connect up the ports P, Y and Z (the L ports remain unconnected).
- Set input signals Yn, X1, X2, X3 etc, step by step and check the outputs A1, A2, A3 etc., plus Yn+1.
- Explain in writing:
  – the signal exchange between the two stepper modules
  – the functioning of the sequencer.
- Draw the displacement-step diagram with signal lines (extend it to include a function diagram).
- Design and draw the circuit diagram.
- Compare your solution with the proposed solution.
- Construct the control system on the profile plate and check that it functions correctly.
- Slow down the motion sequences by moving the sensors to the side and operating manually or by installing one-way flow control valves.
- Note down the valves actuated in each step.
- Introduce faults into each others control circuits and then try to eliminate these systematically using the displacement-step or function diagram.
- Disconnect, sort and check the equipment set to ensure it is complete!

Problem description

Housing parts coming from a drilling and milling station are to be cleaned.

Cylinder (1A) pushes the part to be cleaned from the conveyor belt (W) on to a parts carrier (X). The part is clamped by cylinder (2A) and cylinder (3A) transports it through the washing cabin (Y). Once the washing process is complete, cylinder (2A) unclamps the part and actuator (4A) pushes it onto the conveyor belt (Z). Cylinder (3A) returns the parts carrier to its initial position. The control system is once more located in the initial position.

Pressing the START button enables the introduction of a new single cycle. Three roller lever valves (1S1, 1S2 and 2S1), three proximity switches (3S1, 3S2 and 4S1) and a back pressure valve (4S2) are installed.

The transfer cylinder (3A) does not extend unless the roller lever valve (1S1) is actuated and a pressure of p = 4 bar (400 kPa) has been attained in the piston area of the clamping cylinder. The pressure in cylinder (2A) is indicated by a pressure gauge (0Z3). The last step in the cycle should be carried out as quickly as possible.

Abbreviated notation

1A+ 1A– 3A+ 2A– 4A+ 4A– 3A–
2A+

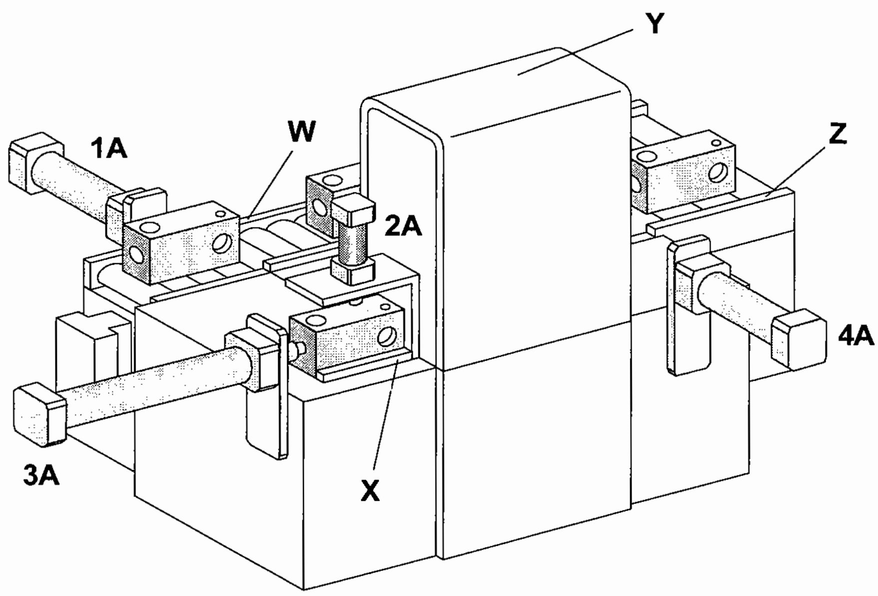


Fig. 12/1: Positional sketch

Subject

Pneumatics

Title

Flat grinding machine

Training aim

- Indirect activation of three actuators with three pilot operated final control elements.
- Realisation of a **sequence control system using two stepper module units**.
- Repeated activation of an actuator within the cycle.
- Construction of an **Input circuit with protected control air** and the functions: EMERGENCY-STOP, START and RESET.
- Use and adjustment of sensors (roller lever valves, pneumatic proximity switches and a back pressure valve).
- Realisation of an AND-connection of acknowledgement signals for pressure and end position sensing.

Exercise

- Draw the displacement-step diagram with signal lines (extend it to include the function diagram).
- Design and draw the circuit diagram without marginal conditions.
- Construct the partial control on the profile plate and check the working cycle.
- Extend the circuit diagram by adding the marginal conditions.
- Assemble your control system and check all functions, in particular the EMERGENCY-STOP situation, at every step.
- Compare your solution with the proposed solution.
- Disconnect, sort and check that the equipment set is complete!

Problem description

Pre-machined guide rails are placed on a flat grinding machine by hand, clamped pneumatically and ground on the righthand and lefthand shoulder.

Once the single-acting clamping cylinder (1A) has reached the forward end position **and** a pressure of p = 4 bar (400 kPa) has built up in the piston area, the double-acting feed cylinder (2A) with exhaust air throttled on both sides carries out a double stroke. The righthand shoulder is ground. The double-acting transverse feed cylinder (3A) extends before cylinder (2A) executes the double stroke and subsequently the lefthand shoulder is ground. When cylinder (3A) has reached the retracted end position, clamping cylinder (1A) releases the workpiece.

Three roller lever valves (1S1, 3S1, 3S2), two proximity switches (2S1 and 2S2) and a back pressure valve (1S2) are used as limit switches. The clamping pressure of cylinder (1A) is monitored via a pressure gauge.

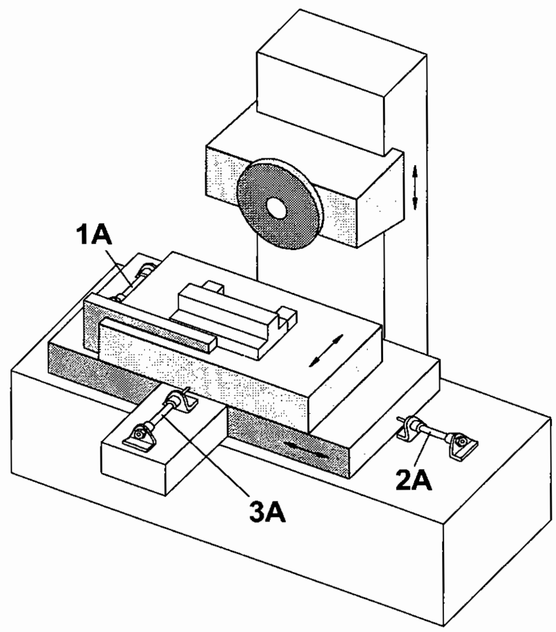
Marginal conditions

The control air supply for the sequencer is protected by a self-holding circuit. A single cycle is introduced by actuating the START button . Actuation of the EMERGENCY-STOP mushroom actuator interrupts the self-holding circuit, the final control elements of actuators (1A) and (3A) receive no further activation and the feed cylinder (3A) is exhausted on both sides. Before EMERGENCY-STOP unlatching, the sequencer and actuating part are set by a second push-button valve.

Abbreviated notation

1A+ 2A+ 2A– 3A+ 2A+ 2A– 3A– 1A–

Fig. 13/1: Positional sketch



Pneumatics — *Subject*

Stacking device — *Title*

Training aim

- Indirect activation of three actuators by three pilot actuated final control elements.
- Repeated activation of an actuator within the cycle.
- **Use of a vacuum device** (vacuum suction nozzle/suction cup, adjustable vacuum actuator).
- Realisation of a **sequence control with two stepper modules**.
- Design of input circuit with protected control air and the functions: START, EMERGENCY-STOP and RESET.
- Use of a counter to limit the number of cycle repetitions.
- Use of sensors.

Exercise

- Draw the displacement-step diagram with signal lines.
- Design and draw the circuit diagram without the marginal conditions and preselect counter.
- Construct a partial control system and check the cycle. (Is it possible to simulate the contact of the suction cup on the soap?)
- Extend the circuit diagram in accordance with the problem description.
- Construct the control system on the profile plate and check all functions.
- Compare your solution with the proposed solution.
- Disconnect, sort and check that the equipment set is complete!

Problem description

A stacking device feeds three bars of household soap (X) from a slide (Y) to a cardboard box (Z). Once the vertically arranged double-acting lifting cylinder (1A) with hollow piston rod has extended, the vacuum suction cup (3A) is actuated. A bar of soap (X) is picked up by the suction cup. Switching of the adjustable vacuum actuator causes the lifting cylinder (1A) to retract. The horizontally arranged transfer cylinder (2A) (pneumatic linear drive) conveys the soap (X) to the box (Z), then the lifting cylinder (1A) extends once again and the vacuum generator (3A) is switched off. The soap (X) drops into the box (Z). The lifting cylinder (1A) retracts. Next, the transfer cylinder (2A) returns to its normal position above the slide. If a START button valve is pressed, a pneumatic counter causes the stepper cycle to run through three times before the controller stops in the initial position. Two roller lever valves (1S1 and 1S2) and two pneumatic sensors (2S1 and 2S2) are used as limit switches.

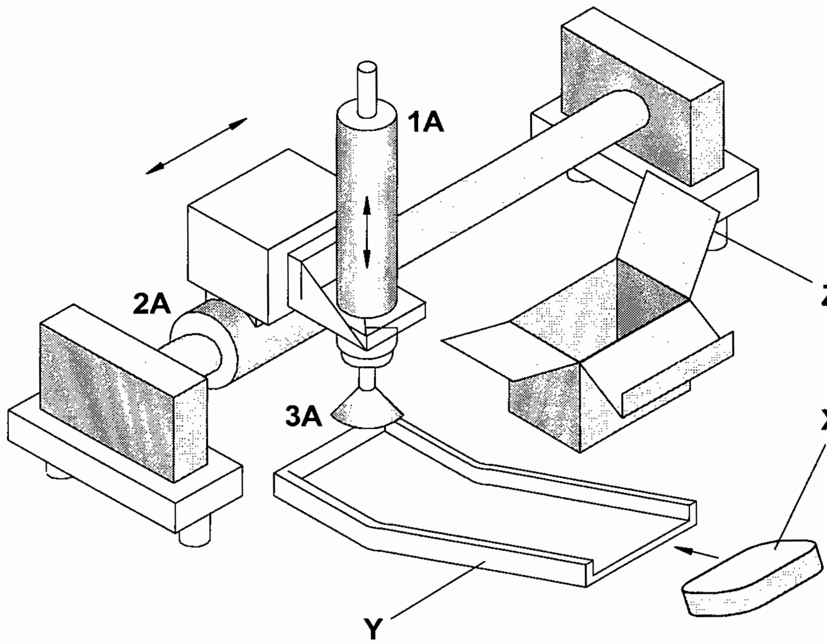
Marginal conditions

The control air supply for the sequencer is protected by a self-latching circuit. Self-latching is interrupted by means of the EMERGENCY-STOP mushroom actuator. The final control valves can no longer be activated. Before EMERGENCY-STOP unlatching, the sequencer and the actuating section are reset by a second push-button valve (RESET).

Abbreviated notation

1A+ 3A+ 1A– 2A+ 1A+ 3A– 1A– 2A–

Fig. 14/1: Positional sketch



Subject

Pneumatics

Title

Separation of packages of varying height

Training aim

- Indirect activation of three actuators with three pilot actuated final control elements.
- Repeated activation of an actuator during a cycle.
- Realisation of a **control system with program selection** by skipping program sections.
- **Use of vacuum generator** (actuator: vacuum generator/suction cup, sensor: adjustable vacuum actuator).
- Realisation of a sequence control using two stepper modules.
- Design of an input circuit with protected control air and the functions: START, EMERGENCY-STOP and RESET.
- Use and adjustment of sensors (roller lever valve, proximity switch, adjustable vacuum actuator and signal inversion).

Exercise

- Draw the displacement-step diagram with signal lines for program I.
- Design and draw the circuit diagram without the marginal conditions and the program selection (for program I).
- Construct the partial control system and check the operating cycle. (How can the impact of the suction cup on the package be simulated during the extension of the lifting cylinder (1A)?)
- Draw the displacement-step diagram with signal lines for program II.
- Extend the circuit diagram in accordance with the problem description.
- Construct your control system on the profile plate and check all functions.
- Compare your solutions with the proposed solution.
- Disconnect, sort and check that the equipment set is complete!

Problem description

The pneumatic transfer machine removes packages of varying height from the conveyor belt feed (X) and placed them on a weighing device (Y) to determine the height.

A selector switch enables preselection of program I or II. Each time the START button is pressed, a package is transferred. The processing station is designed for program I. Two roller lever valves (1S1 and 1S2), two proximity switches (2S1 and 2S2) as well as the adjustable vacuum actuator are used as sensors.

Program I

The vertically arranged double-acting cylinders (1A) with hollow piston rod and the vacuum generator (3A) are activated simultaneously. Cylinder (1A) extends with exhaust air heavily throttled. When the piston rod with attached suction cup contacts a package (Z), a vacuum is generated and the adjustable vacuum actuator (0V4+) switches through. This causes the lifting cylinder (1A) to retract with exhaust air throttled. The horizontally arranged transfer cylinder (2A) (pneumatic linear drive) conveys the package to the weighing device. When the lifting cylinder (1A) has reached the forward end position, the vacuum suction nozzle switches off. The package drops from a limited height on to the weighing device. Lifting cylinder (1A) retracts. Next, the transfer cylinder (2A) returns to the initial position.

Program I

When the selector switch is set to program II, the package is once again picked up by the lifting cylinder (1A) and transported by the transfer cylinder (2A) across to the weighing table. Then, however, the vacuum generator (3A) is switched off. The package drops from a considerable height on to the stationary weighing table. Next, the transfer cylinder (2A) returns to the initial position. This cycle is achieved by suppressing the fourth sequence step (1A+) and simulating the acknowledgement signal (1S2).

Marginal conditions

The control air supply for the sequencer is protected by means of a self-latching circuit. When the EMERGENCY-STOP mushroom actuator is actuated, the self-holding circuit is interrupted. The final control elements receive no further actuation. Before EMERGENCY-STOP unlatching, the sequencer and actuating section are reset by a second valve with push button (RESET).

Abbreviated notation

Program I

1A+	**0V4+**	**1A–**	**2A+**	**1A+**	**3A–**	**1A–**	**2A–**
3A+					**0V4–**		

Program II

1A+	**0V4+**	**1A–**	**2A+**		**3A–**		**2A–**
3A+					**0V4–**		

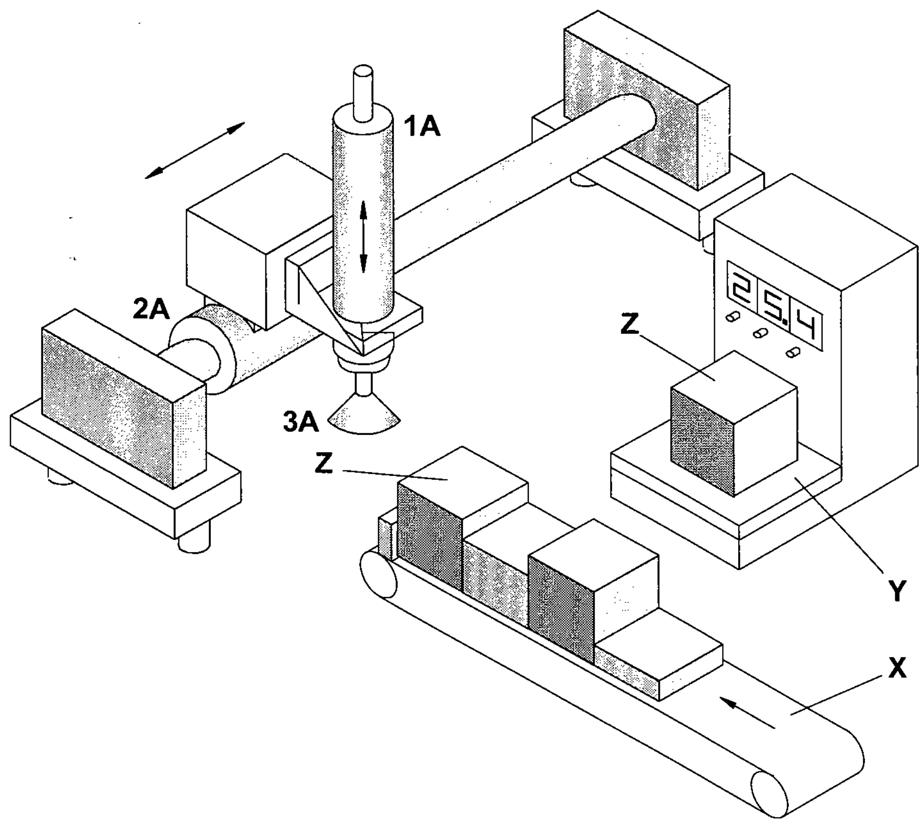


Fig. 15/1: Positional sketch

Exercise 16

Stepper controllers with parallel program

Various different sequence variations can be realised by means of stepper technology.

- Jumping of program sections
- Step repetitions
- Alternative programs
- Parallel programs.

Here too, owing to its simple, clear structure, stepper technology enables systematic solution of the widest variety of motion sequences.

In exercise 15, selection can be made between program I and II. The control is designed for program I. Program II, one step is not executed, i.e. **jumped over**. This is achieved through blocking of the output signal and simulation of the acknowledgement signal. Variable **step repetition** is discussed in exercise 8. The number of repetitions is preselected via a counter. Realisation of **alternative programs** (EITHER-OR programs) using the sequencer (Quickstepper) is shown in exercise 18. Alternative programs can be constructed in the same way using the sequencer.

The following exercise 16 is a simple example of a **parallel program**. The memory module ensures easy operation.

A control solution employing a sequencer in which several programs run simultaneously on machines or production equipment can be obtained relatively easily. Such solutions often involve parallel programs with a common subprogram at the beginning and/or end of the cycle. This might be, for example, a common workpiece transportation program, to which are connected various processing stations. Once the workpieces have been transported, the common program is divided up into individual subprograms independent of one another. Subprograms 1, 2, 3 etc. start simultaneously. Depending on the problem, the subprograms are either collected together via an AND-connection to form a common program end or else they run through the cycle end independent of one another.

16 Transfer line

Sequence control with parallel program and common subprogram at the start. Operating modes AUTOMATIC/MANUAL and CONTINUOUS CYCLE/SINGLE CYCLE are obtained with the command (memory) module and a directional control valve with one switch. 3/2-way push-button valves enable the functions START, STOP DURING CYCLE and RESET. The impulse ejector - an actuator- is also activated via a final control element (3/2-way valve). This is a normally open valve.

Subject: *Pneumatics*

Title: ***Transfer line***

Training aim

- Indirect activation of six actuators by double pilot valves (a rodless linear drive, two single-acting cylinders, two feed units with hydraulic cushioning cylinders and an impulse ejector).
- Design and construction of a **control system using a parallel program**. One stepper module, type TAA, and two stepper modules, type TAA/TAB are used. After a common program with two stages (parts feed), the program cycle is separated into two program sections with four stages (processing station X) and three stages (processing station Y with parts ejection) which run independently of one another but start together.
- Design and realisation of a **basic circuit for a complete control unit**. The command memory module is to be used here (as a substitute for this all functions of the command memory module can be implemented using individual components from equipment sets TP101 and TP102):
  - AUTOMATIC/MANUAL operating mode preselect
    (5/2-way valve with selector switch)
  - CONTINOUS CYCLE/SINGLE CYCLE operating mode preselect
    (3/2-way valve with selector switch)
  - START button with START memory
    (3/2-way valve with push button, memory module)
  - STOP button for STOP at END OF CYCLE
    (3/2-way valve with push button).

  If the MANUAL operating mode is selected, both actuators and processor must assume the initial position when the RESET key is pressed.
- Use of four roller lever valves and three proximity switches as sensors.
- Realisation of reversal of movement of an actuator, in this case of half the maximum stroke (processing station 1).
- Activation of an impulse ejector by the sequencer. A time delay valve is used for this.

Exercise

- Draw the displacement-step diagram with signal lines.
- Design and draw the circuit diagram without marginal conditions.
- Construct the part control and check its operating cycle.
- Extend the circuit diagram to incorporate the marginal conditions.
- Construct the control on the profile plate and check all functions (AUTOMATIC/MANUAL, RESET, SINGLE CYCLE/CONTINUOUS CYCLE, START and STOP during CYCLE END). What effect does inadvertent wrong operation of the bush button and switches have?
- Compare your solution with the proposed solution.
- Draw up the function chart for the control.
- Plot the displacement-time diagram for the control (stop watch).
- Disconnect, sort and check that the equipment set is complete!

Problem description

Rectangular blanks are drilled horizontally and vertically at two drilling stations (X) and (Y) arranged in series. The first blank is pushed out of the gravity feed magazine and fed to the drilling station (X), where the horizontal drill hole (5 mm diameter) is produced. Pushing the second blank from the magazine moves the first workpiece from the processing station (X) to station (Y). The vertical drill hole (20 mm diameter) is produced here and the horizontal hole is blown free of swarf by an impulse ejector. When the third blank is pushed out, the first workpiece drops into a transfer container.

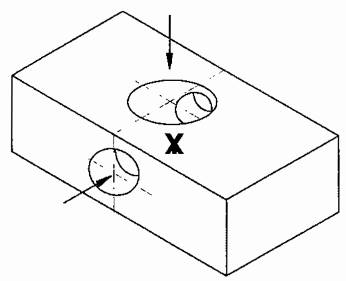


Fig. 16/1: Werkstück

Drilling station (X) is equipped with a horizontally arranged feed unit (3A) with hydraulic cushioning cylinder. A through hole of 5 mm diameter is produced by deep drilling by means of swarf removal stroke.

Drilling station (Y) is equipped with a vertical feed unit (4A) with hydraulic cushioning cylinder. When the 20 mm diameter hole is complete, the crosswise hole is blown free of swarf by an impulse ejector (E). Carrier cylinders (2A1) and (2A2) are used to transport workpieces of varying lengths.

Single cycle

Once the START button has been actuated, the first stepper module activates the ejector cylinder (1A) (linear drive) and the two carrier cylinders (2A1) and (2A2) (single-acting cylinders) simultaneously. The undrilled blank is pushed out of the gravity feed magazine and transferred to processing station (X). Acknowledgement by sensor 1S2 causes the first stepper module to be switched to the second stage. Cylinders (1A), (2A1) and (2A2) travel into the retracted end position; sensor 1S1 is actuated once again.

The signal flow in the processor is separated after the first stepper module. Two program sections which start up simultaneously (1S2) run through in parallel. Feed unit (3A) for the deep-hole drilling motion sequence 3A+ 3A- 3A+ 3A- is controlled by a four-stage sequencer. Roller lever valves (3S1) and (3S2) in the end positions with (3S3) at half the maximum stroke, signal the position of the actuator (3A).

When the second blank is ejected, the first workpiece arrives at drilling station (Y). The vertical feed unit (4A) (motion sequence 4A+ 4A-) is controlled by a three-stage sequencer. Two roller lever valves 4S1 and 4S2 monitor the end positions. The last stepper module in the second part program controls the impulse ejector (5A). Resetting of the final control valve is effected via a time delay valve (t = 2 sec.). The Yn+1 signals for both parallel programs are directed back to the memory module via a dual-pressure valve.

Marginal conditions

The control air supply for the sequencer modules is effected via a memory module. Operating modes AUTOMATIC/MANUAL, RESET, CONTINUOUS CYCLE/SINGLE CYCLE, START, STOP at END OF CYCLE are included. Clamping of workpieces at processing stations (X) And (Y) are not taken into account.

Abbreviated notation

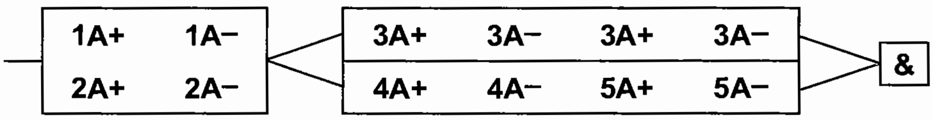
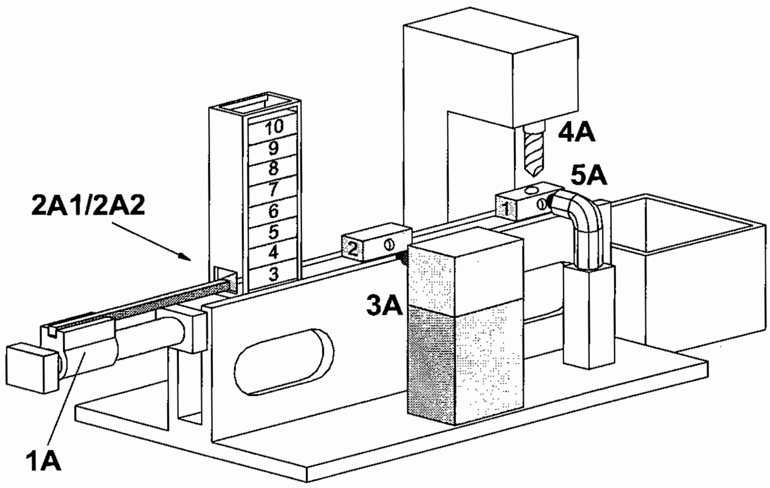


Fig. 16/2: Positional sketch



Exercises 17 and 18

Control systems using a sequencer (Quickstepper)

In this group of exercises, the components already familiar (valves, cylinders etc.) are combined - for training purposes - to form extensive controls. The focal point of these exercises is a pneumatic sequencer, the Quickstepper. The Quickstepper is an additional component in the TP100 Technology Package. It is, however, not a component of the TP 101 (basic level) or TP102 (advanced level) equipment sets. As far as the external operation is concerned, the Quickstepper is very similar to the sequencer already dealt with (exercises 5-16). However, it offers important, additional operating features. We see it as a “black-box”. The internal operation - pneumatically actuated mechanism - is of no interest to us; for these two exercises, we simply need to know how to connect it up correctly and to recognise the considerable simplification of the circuit. Its specific advantages over the stepper modules come to light in combination with the command (memory) module (initially used in exercise 16).

Exercise 17 (drilling of cast iron frames) is a simple example of the application of the sequencer with AUTOMATIC/MANUAL mode and a START button. The command (memory) module will be addressed under ‘Further development’. Two different circuit variations (B) and (C) explain the interplay between sequencer and input section. Exercise 18 is the most extensive example in this collection requiring the most time. The processor activates five actuators. The machine (reversing device for sandblasting can be influenced by the memory module and seven switches or push buttons).

17 Drilling of cast iron frames

Sequence control with the functions: AUTOMATIC/MANUAL, START, SET/STEP mode and step display. An actuator is activated four times in the cycle. The number of cycles is limited by a counter.

Circuit version B:
The command (memory) module is replaced by a 3/2-way pneumatic valve.

Circuit version C:
The functions SINGLE CYCLE/CONTINUOUS CYCLE and STOP at END OF CYCLE are constructed with the aid of the command (memory) module.

18 Reversing device for sandblasting

Sequence control with program selection (two alternative programs). The EITHER-OR PROGRAM SELECTION is achieved by jumping over a program section (blocking of the output signals and simulation of the input signals). The functions AUTOMATIC/MANUAL, CONTINUOUS/ SINGLE CYCLE, START, STOP at END OF CYCLE are thus obtained. In the input section, a roller lever valve is used for magazine sensing. During the cycle an actuator is controlled in combination with a time delay.

Subject: *Pneumatics*

Title: ***Drilling of cast iron frames***

Training aim

- Indirect activation of three actuators by three pilot operated final control elements.
- Repeated actuation of an actuator within the cycle (4 double strokes).
- Realisation of a **control system using a sequencer** (Quickstepper). We are limited here to AUTOMATIC/MANUAL operating modes (selector switch) and the START function (push button).
- To recognise the new possibilities opened up by MAN.STEP (manual stepping) operating mode and the OUTPUT function and the step display of the sequencer.
- Use and adjustment of sensors (roller lever valve, back pressure valve, pneumatic proximity switch).
- Use of a pneumatic preselect counter to limit the number of cycle repetitions (use of the input module).
- Development and construction of circuit variant B.
- Development and construction of circuit variant C (use of the input module and implementation of operating modes AUTOMATIC/ MANUAL and CONTINUOUS CYCLE/SINGLE CYCLE as well as the START and STOP at END OF CYCLE functions).
- Familiarisation with the operating functions of sequencer and input module.

Exercise

- Start by working with just the sequencer (without actuators and sensors, short-circuiting of inputs and outputs). Determine the operating pressure at which the sequencer runs through the quickest?
- Explain in writing the method of operation of the sequencer (black-box).
- Draw the displacement-step diagram.
- Develop and draw the circuit diagram.
- Construct the control system on the profile plate.
- Keep a check on all the operating functions.
- Have some random faults introduced in your control system and develop a system for fault finding.
- Disconnect, sort and check that the equipment set is complete!

Problem description

Four through holes are drilled into rectangular frames. The parts are inserted by hand and clamped by an eccentric cam.

Feed unit (1A) with hydraulic cushioning cylinder is vertically arranged (Z-axis). The transfer cylinders (2A) and (3A) move the table into the X- and Y-directions so that drilling positions (1), (2), (3) and (4) are approached in series.

Once the START-button has been pressed, the first drill hole is produced using the feed unit (1A). Double-acting cylinder (2A) retracts. The second drilling operation is performed. Once the double-acting cylinder (3A) has retracted, feed unit (1A) performs the third double stroke. When cylinder (2A) once again moves to the forward end position, the fourth hole is drilled. In step 12, cylinder (3A) extends once again. The initial position is obtained. Three roller lever valves (1S2, 1S3 and 2S1), two proximity switches 3S1 and 3S2) and a back pressure valve (2S2) are used as limit switches.

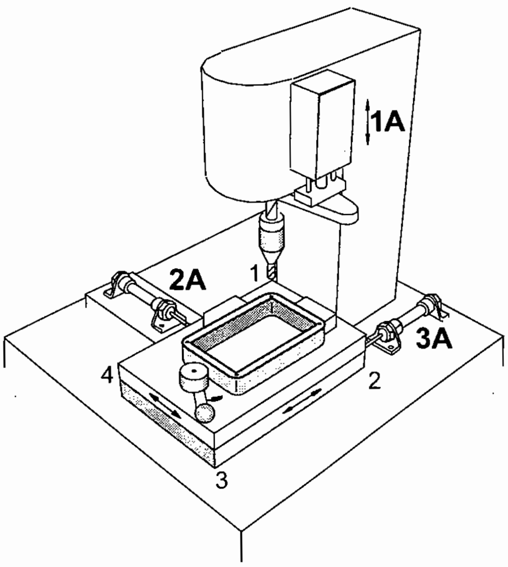
Marginal conditions

The sequencer is switched from AUTOMATIC to MANUAL by a valve with selector switch, thereby making it possible for the cycle to be run through step by step. To exlude the possibility of the drill being overloaded, a specific number of drill holes are specified as a "standard quantity" - 80 (8) drilling operations. Once this figure has been reached, re-starting is prevented by a preselect counter.

Abbreviated notation

1A+ 1A– 2A– 1A+ 1A– 3A– 1A+ 1A– 2A+ 1A+ 1A– 3A+

Fig. 17/1: Positional sketch



Subject: *Pneumatics*

Title: ***Turning unit for sandblasting***

Training aim

- Indirect activation of five actuators by pilot operated final control valves two double-acting cylinders, one single-acting cylinder, vane actuator, vacuum generator/suction cup).
- Repeated activation of actuators within a cycle in conjunction with a time delay.
- Realisation of **control system using a sequencer** (Quickstepper) and memory module.
- Design and construction of a **control system with program selection** I/II (alternative programs) by skipping program sections suppression of output signals and simulation of input signals).
- Realisation of operating modes AUTOMATIC/MANUAL and CONTINUOUS/SINGLE CYCLE as well as the functions START and STOP at END OF CYCLE.
- Use of a roller lever valve for magazine sensing.
- Use of a vacuum device (actuator: vacuum generator/suction cup, Sensor: adjustable vacuum actuator).
- Use and adjustment of sensors (roller lever valves, pneumatic proximity switches, back pressure valve, adjustable vacuum actuator).
- Management of control functions of sequencer and **input module** through operating with “Black-boxes”.

Exercise

- Draw the displacement-step diagram for program I.
- Design and draw the circuit diagram for program I only and without taking into consideration the components on the control panel (START key only).
- Construction and test of partial control 1.
- Extend the circuit diagram to include the marginal conditions (program I only).
- Construction and test of partial control 2.
- Draw the displacement-step diagram for program II.
- Extend the circuit diagram in accordance with the problem description (alternative program).
- Construct the complete control system and test all the operating functions repeatedly.
- Determine what the effects of inadvertent maloperation of the push buttons and the switches are?
- Insertion of deliberate faults and systematic fault finding.
- Draw up the displacement-time diagram.
- Disconnect, sort and check that the equipment set is complete!

Problem description

Valve blocks are separated (1A) and held (3A) and (5A) by means of this installation. They are then sandblasted (2A) and turned by 180 (3A), (4A) and (5A). Once the opposite surface has been sandblasted, the blocks are put on to a conveyor belt (3A) and (5A).

The control panel is equipped with:

- AUTOMATIC/MANUAL (3/2-way valve with selector switch)
- STOP at END OF CYCLE (3/2-way valve with push button)
- CONTINUOUS CYCLE/SINGLE CYCLE (3/2-way valve with selector switch)
- START (3/2-way valve with push button)
- PROGRAM I/II (5/2-way valve with selector switch)
- Optical display of the initial position (pneumatically actuated).

The following are used for sensing:

- 4 roller lever valves (1S1, 1S2, 2S1 and 3S1)
- 1 back pressure valve (2S2)
- 3 proximity switches (3S1, 4S1and 4S2)
- 1 adjustable vacuum actuator
- 1 additional roller lever valve for gravity feed magazine sensing (simulation by 3/2-way valve with push-button).

Program I

When the START button is pressed, the separating cylinder (1A) pushes a valve manifold to the left out of the gravity feed magazine. At the same time, the vacuum generator (5A) is energised and the transfer cylinder (3A) with hollow piston rod and attached suction cup is actuated.

When cylinder (3A) has reached the forward end position (valve manifold held) and a vacuum has been generated, valve operating cylinder (2A) extends and remains in the forward end position for t = 2 seconds. The valve manifold is sandblasted. When valve cylinder (2A) has reached the retracted end position, the piston rod of the transfer cylinder (3A) retracts with the valve manifold which has been sandblasted on one side. The reversing actuator (4A) turns by 180° and transfer cylinder (3A) extends once again. The opposite side of the workpiece is sandblasted (2A+, t, 2A-). Then, transfer cylinder (3A) with the valve manifold and separating cylinder (1A) retract. Once the vacuum generator (5A) has been switched off (valve manifold drops on to the conveyor belt) and the reversing actuator (4A) has swung back, the cycle is complete. The control is once again in the initial position.

Program II

When the 5/2-way valve with selector switch (program I/II) has reversed and the START button is actuated, program II runs. The valve manifolds are sandblasted on one side only and transported away, i.e. movements 3A+, 4A+, 3A+, 2A+ and 2A- as well as 4A- are omitted.

Marginal conditions

If the 3/2-way valve with selector switch (AUTOMATIC/MANUAL) is reversed, step mode can be effected via the MAN.STEP key of the sequencer. SETTING MODE is possible by setting the OUTPUT switch to zero.

Abbreviated notation

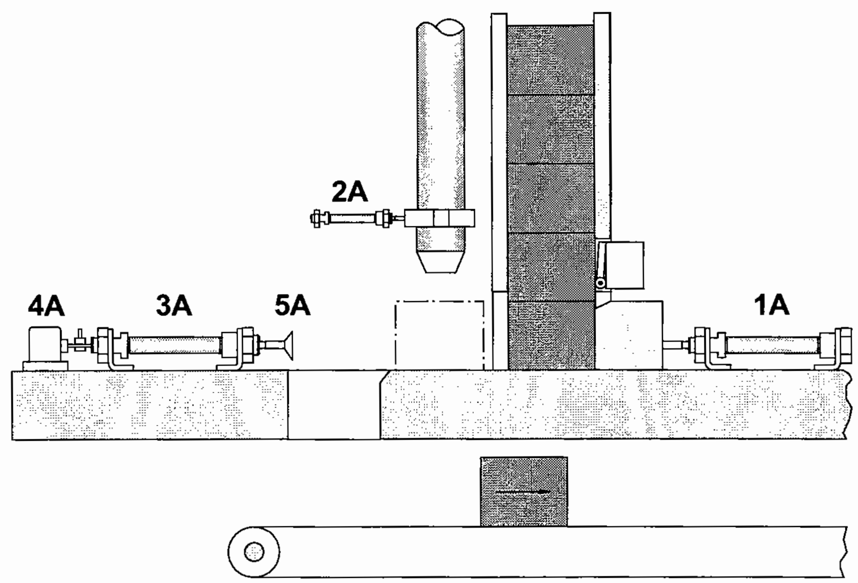
Program I

1A+	**3A+**	**2A+**	**2A–**	**3A–**	**4A+**	**3A+**	**2A+**	**2A–**	**1A–**	**4A–**
	5A+								**3A–**	**5A–**

Program II

1A+	**3A+**	**2A+**	**2A–**						**1A–**	**5A–**
	5A+								**3A–**	

Fig. 18/1: Positional sketch



Exercises 19 and 20

A distinction is made between sequence controls (sequential controls) and logic controls based on the type of signal processing in use. Exercises 1 to 18 deal with sequence controls. Exercises 19 and 20 refer to logic controls.

Logic controls are binary controls. They may, for example, be developed with the aid of logic algebra. The pneumatic binary adder (exercise 19) is an example of a logic control with response to setpoint changes. In the 20th exercise, this adder is extended to form a logic control with latching characteristics. A pneumatic "mini computer" is constructed.

In the system circuit diagram, a distinction is made between the:

- actuator (e.g. double-acting cylinder)
- processor (e.g. dual-pressure valve)
- sensor (e.g. directional control valve with pressure switch).

The binary figures zero and one can be represented by a single cylinder:

- cylinder retracted signifies zero
- cylinder extended signifies one.

Four binary adders can be shown by two cylinders. A maximum of eight digits can be shown by three actuators.

Translation table

Decimal	0	1	2	3	4	5	6	7
Binary	000	001	010	011	100	101	110	111

19 Pneumatic binary adder

Logic control with response to set point changes. Two addends are input using push-button valves. The processor (binary adder) is to be developed. Three actuators indicate the result of the calculations for as long as the push buttons are actuated.

20 Pneumatic binary adder with memory function

Logic control with latching properties. The five push-button valves have the functions: counter value input (2 push buttons), addition command, result command, reset command. The memory processor must be developed. Three actuators indicate the first addend, second addend and the result of the calculations.

Subject: *Pneumatics*

Title: ***Pneumatic binary adder***

Training aim

- Solve the "Black box problem" which has been set.
- Realisation of a **logic control with response to set point changes**.
- Draw up and evaluate the truth table.
- Set up and evaluate Boolean equations.
- Pneumatic realisation of a logic EXCLUSIVE-OR.
- Pneumatic realisation of Boolean equations.
- Reliable calculations in the binary system using an adding counter.

Exercise

- Draw up the truth table (A2, A1, B2, B1 = C3, C2, C1, - decimal result).
- Derive three Boolean functions from this:
  C1 = f (A1, B1), C2 = f (A1, B1, A2, B2), C3 = f (A1, B1, A2, B2).
- Systematically develop the logic diagram for the processor (0Z3) with the aid of three equations or using the truth table (3 AND-functions, 3 EXCLUSIVE-OR functions and one OR-function each with two inputs).
- How is an EXCLUSIVE-OR realised pneumatically?
- Draw the pneumatic circuit diagram.
- Construct the circuit and check the result of the calculations.
- Disconnect, sort and check that the equipment set is complete (the circuit design will be needed for exercise 20).

Problem description

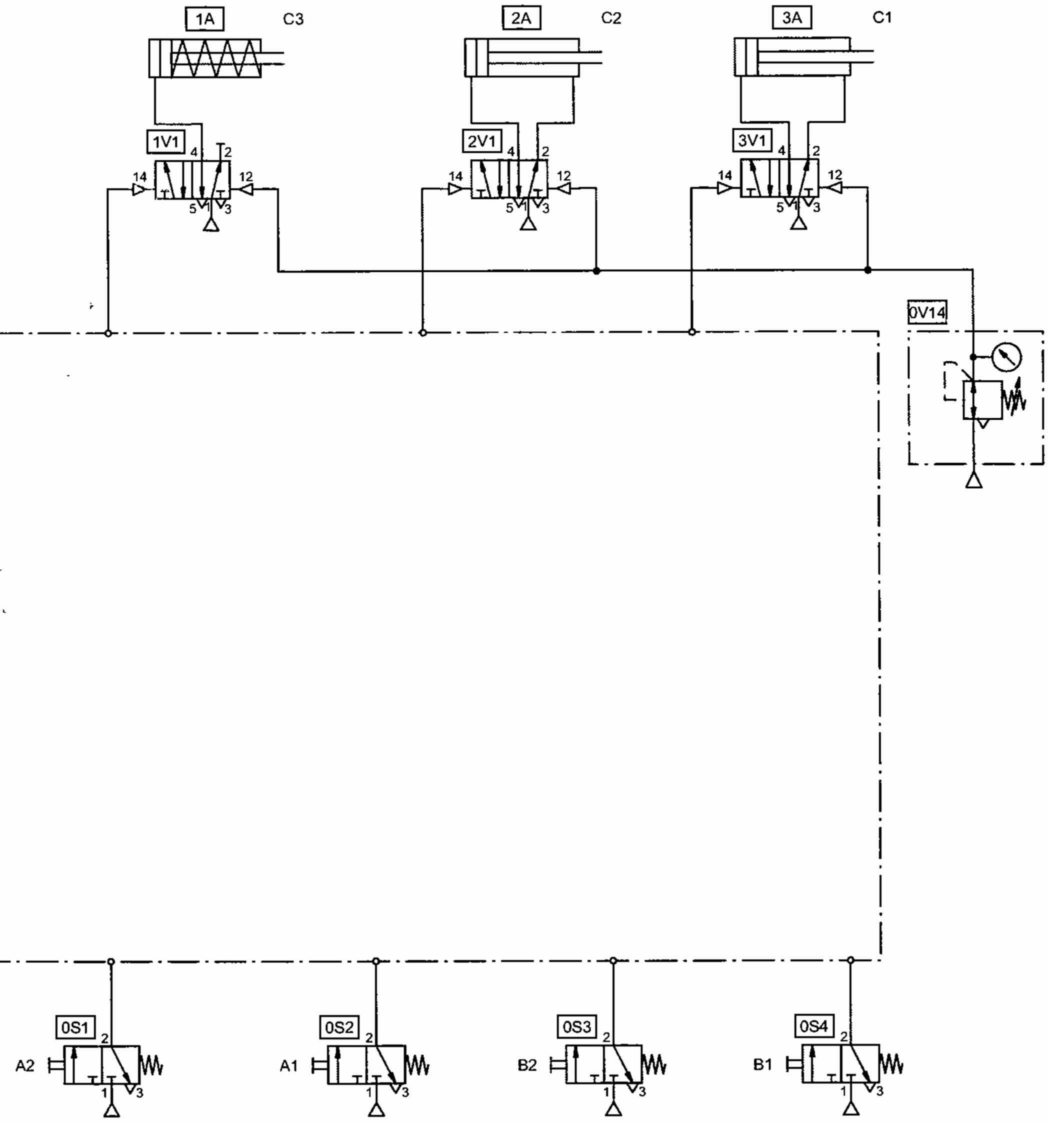
Binary numbers 000, 001, 010 ... 111 can be represented by three cylinders (C1 = 2^0 (3A), C2 = 2^1 (2A) and C3 = 2^2 (1A)). Three final control elements (1V1), (2V1) and (3V1) control the indicator cylinders. The first addend is input by two 3/2-way valve using push-buttons A1 and A2 (A1 = 2^0, A2 = 2^1). The second addend is input using input push buttons B1 and B2 simultaneously (B1 = 2^0, B2 = 2^1).

Develop a purely pneumatic processor (binary adder) (0Z3) with four inputs (A1 and A2 as well as B1 and B2) and three outputs (C1, C2 and C3). The pneumatic binary incremental counter should be able to display all conceivable additions using its indicator cylinders provided the input push buttons have been pressed.

	Push-button			*Push-button*			*Cylinder*		
Input/output	A2	A1	+	B2	B1	=	C3	C2	C1
Power	2^1	2^0		2^1	2^0		2^2	2^1	2^0
Example:									
Binary value	1	1	+	1	0	=	1	0	1
Decimal value	3		+	2		=	5		

- Cylinder extended or push button actuated: signal 1.
- Cylinder retracted or push button unactuated: Signal 0.
- Work with a pressure of p = 5 bar (500 kPa).
- Set the pressure regulator via pressure gauge (0V14) to a pressure of p = 250 kPa (2.5 bar).

Fig. 19/1: Positional sketch



(incomplete circuit diagram)

Truth table

Input push button				Indicator cylinder (result)			
1. Addend		2. Addend		binary			decimal
A2	A1	B2	B1	C3	C2	C1	
2^1	2^0	2^1	2^0	2^2	2^1	2^0	
0	0	0	0				
0	0	0	1				
0	0	1	0				
0	0	1	1				
0	1	0	0				
0	1	0	1				
0	1	1	0				
0	1	1	1				
1	0	0	0				
1	0	0	1				
1	0	1	0				
1	0	1	1				
1	1	0	0				
1	1	0	1				
1	1	1	0				
1	1	1	1				
Allocation not possible							

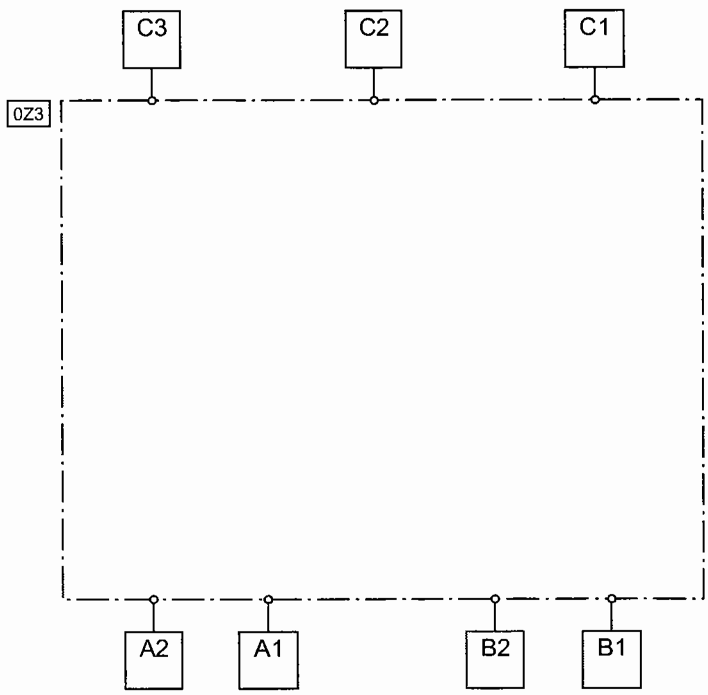
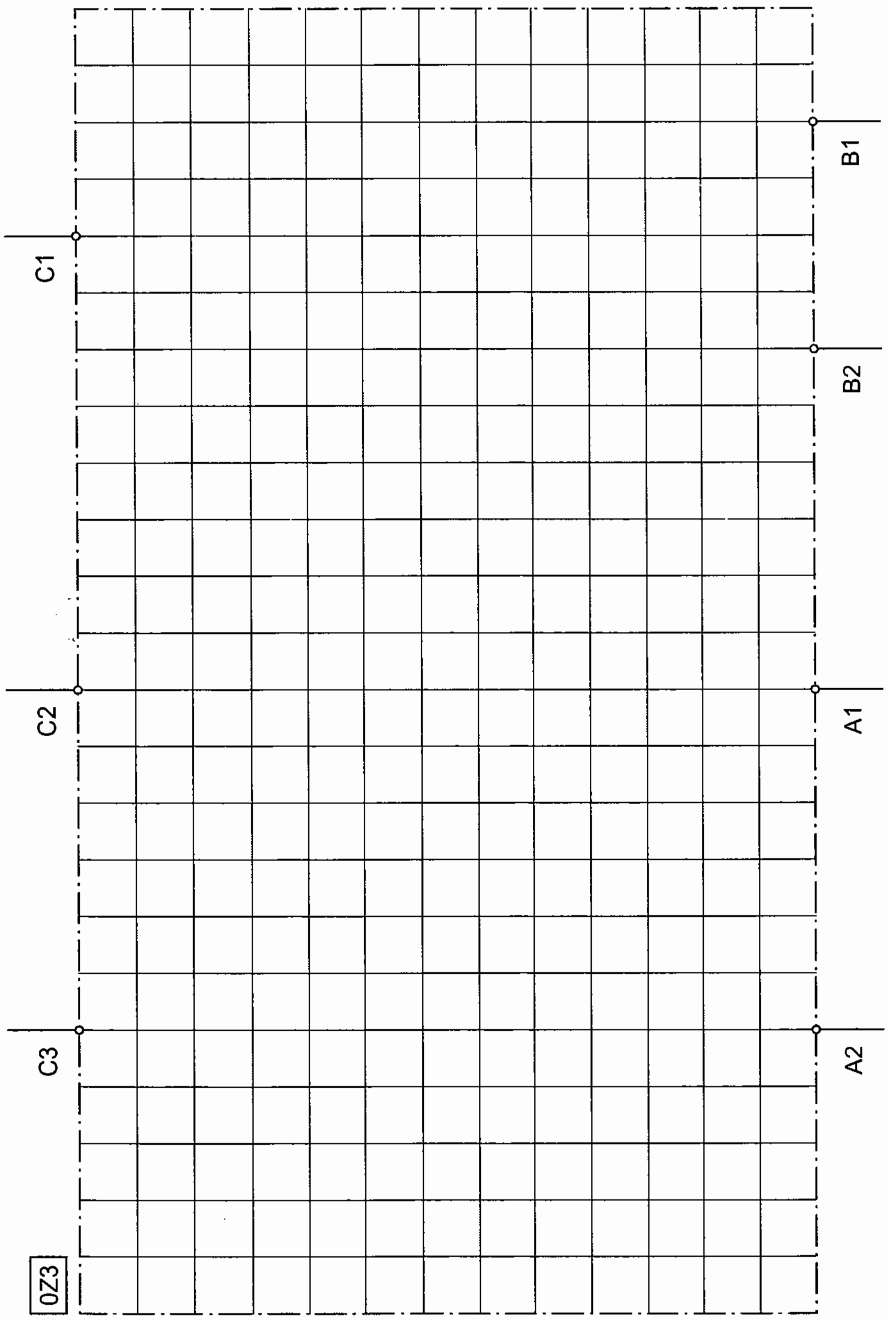


Fig. 19/2: Logic diagram

Fig. 19/3: Circuit diagram



Subject
Pneumatics

Title
Pneumatic binary adder with memory function

Training aim

- Solve the "Black box problem" which has been set.
- Realise a **logic control with latching properties**.
- Memorising binary numbers using pneumatic valves.
- Reliable calculation using a binary adder.

Exercise

- Construct the control for exercise 19 on the upper half of the profile plate (this corresponds to the incomplete circuit diagram shown).
- Familiarise yourself with this control.
- Complete the block diagram of the memory processor (0Z4).
- Develop and draw the circuit diagram of the memory processor (0Z4), you require eight 5/2-(or 3/2-) way double pilot valves.
- Construct the control and check the results of the calculations.
- Disconnect, sort and check that the equipment set is complete.

Problem description

The adding counter realised in exercise 19 has no memory. This means that the result is only displayed for as long as the input push buttons are being actuated (response to set point changes).

Develop a memory processor (0Z4), arranged between the processor (0Z3) and the input keys (0S1), (0S2), (0S3), (0S4) and (0S5). The memory processor has four outputs (inputs of the processor (0Z3)) and five inputs (3/2-way valve with push button).

Adapt the operator functions to those of a conventional pocket calculator.

- Input of the first addend (binary figure 00, 01, 10 or 11) using push buttons (0S1) = A2 = 2^1 and (0S2) = A1 = 2^0, display via actuators (2A) = C2 = 2^1 and (3A) = C1 = 2^0.
- Addition command "+" with push button (0S3), all extended cylinders retract.
- Input of second addend (binary figure 00, 01, 10 or 11) also using push buttons (0S1) = B2 = 2^1 and (0S2) = B1 = 2^0, display of second addend via C2 and C1.
- Result command "=" using push button (0S4), the total is indicated via the actuators (1A) = C3 = 2^2, (2A) = C2 = 2^1 and (3A) = C1= 2^0.
- Reset command "C" by push button (0S5). The processor (5Z) and thus the entire control is transferred into the initial position and a new adding task can be started.
- Example
  The decimal calculation 3 + 2 = 5 (binary calculation 11 + 10 = 101) is executed. Press the push buttons (0S1), (0S2), (0S3), (0S1) and (0S4) in series. Reset via push button (0S5).

(incomplete circuit diagram)

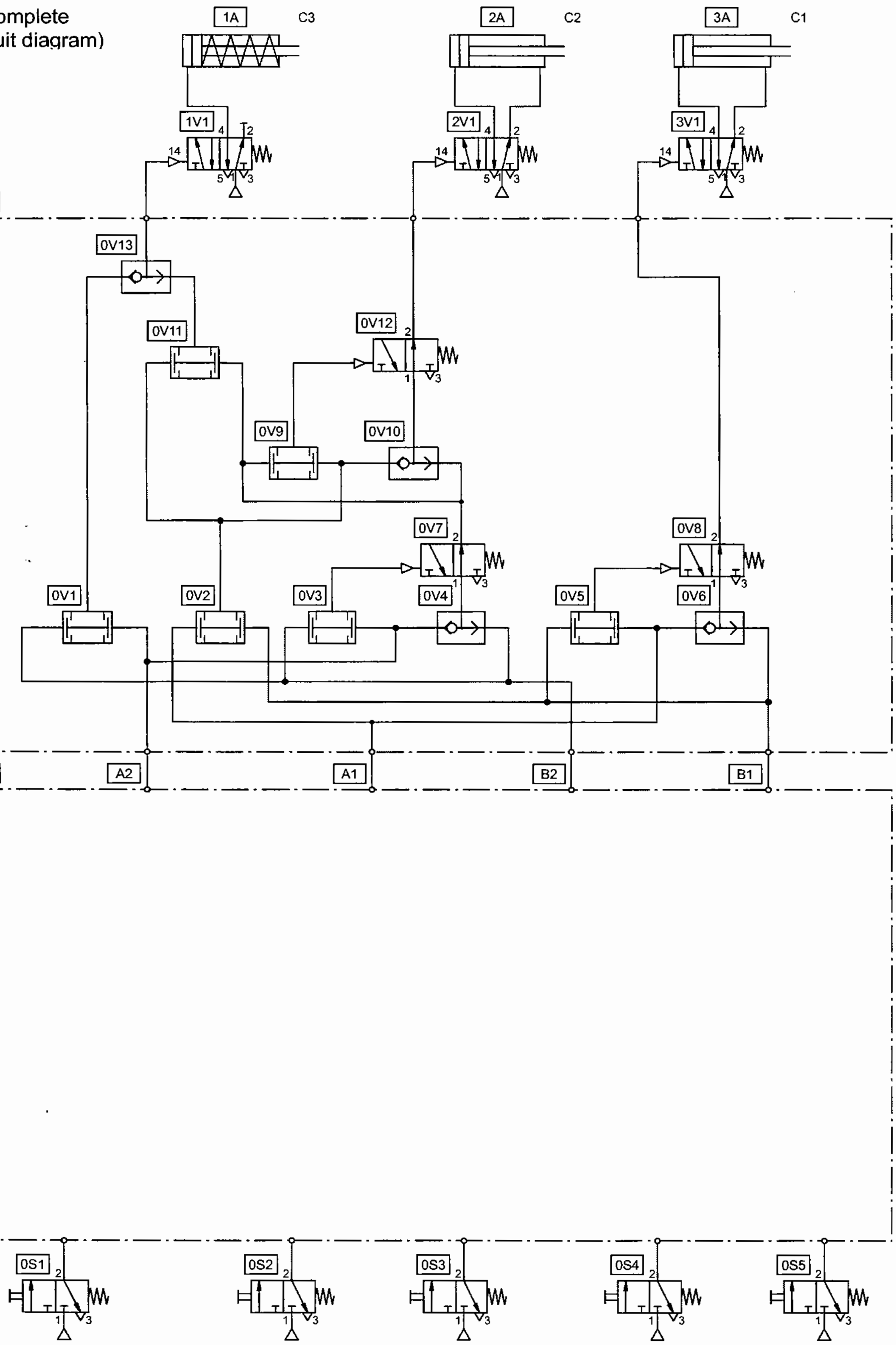


Fig. 20/1: Circuit diagram

Fig. 20/2: Block diagram

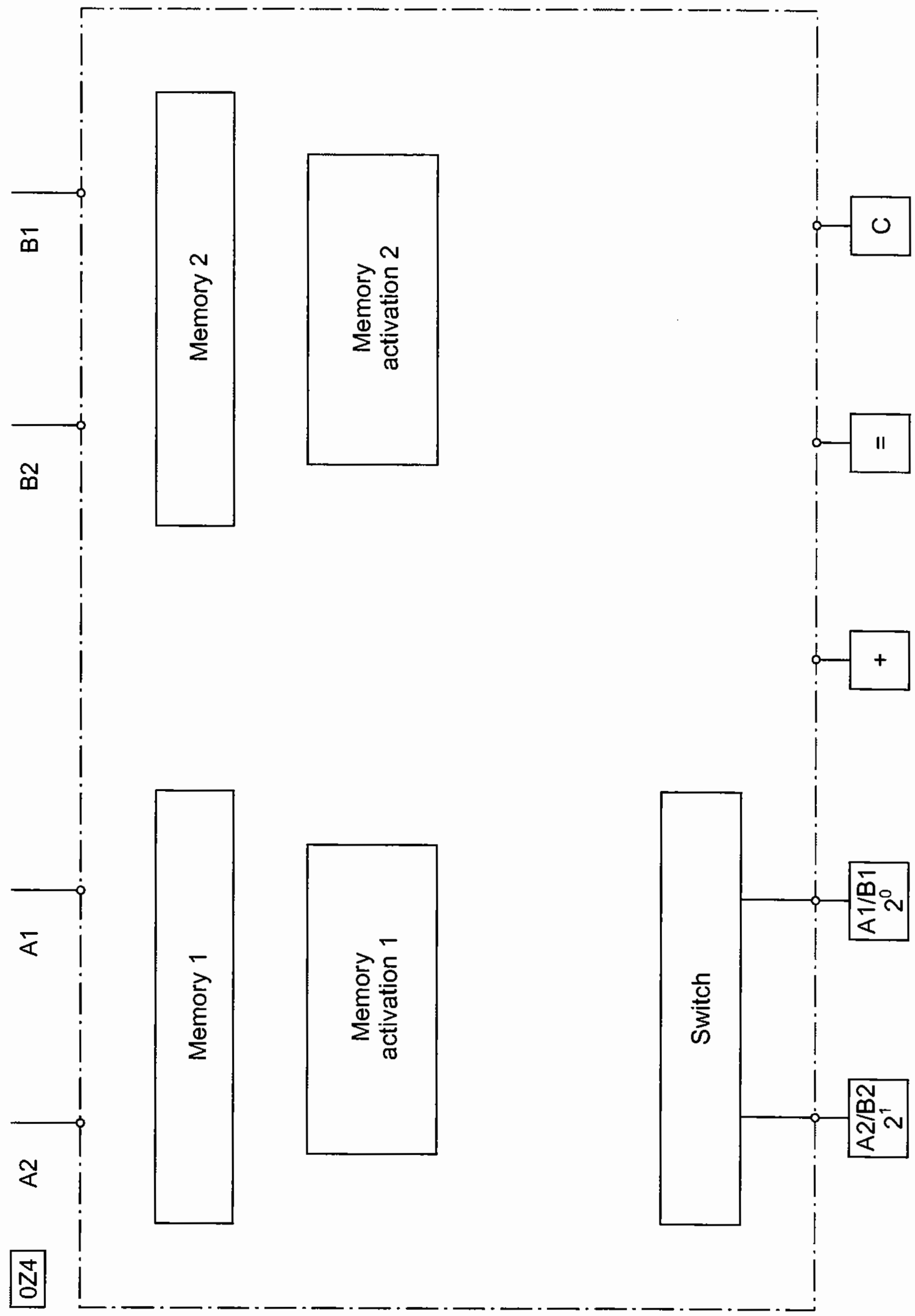
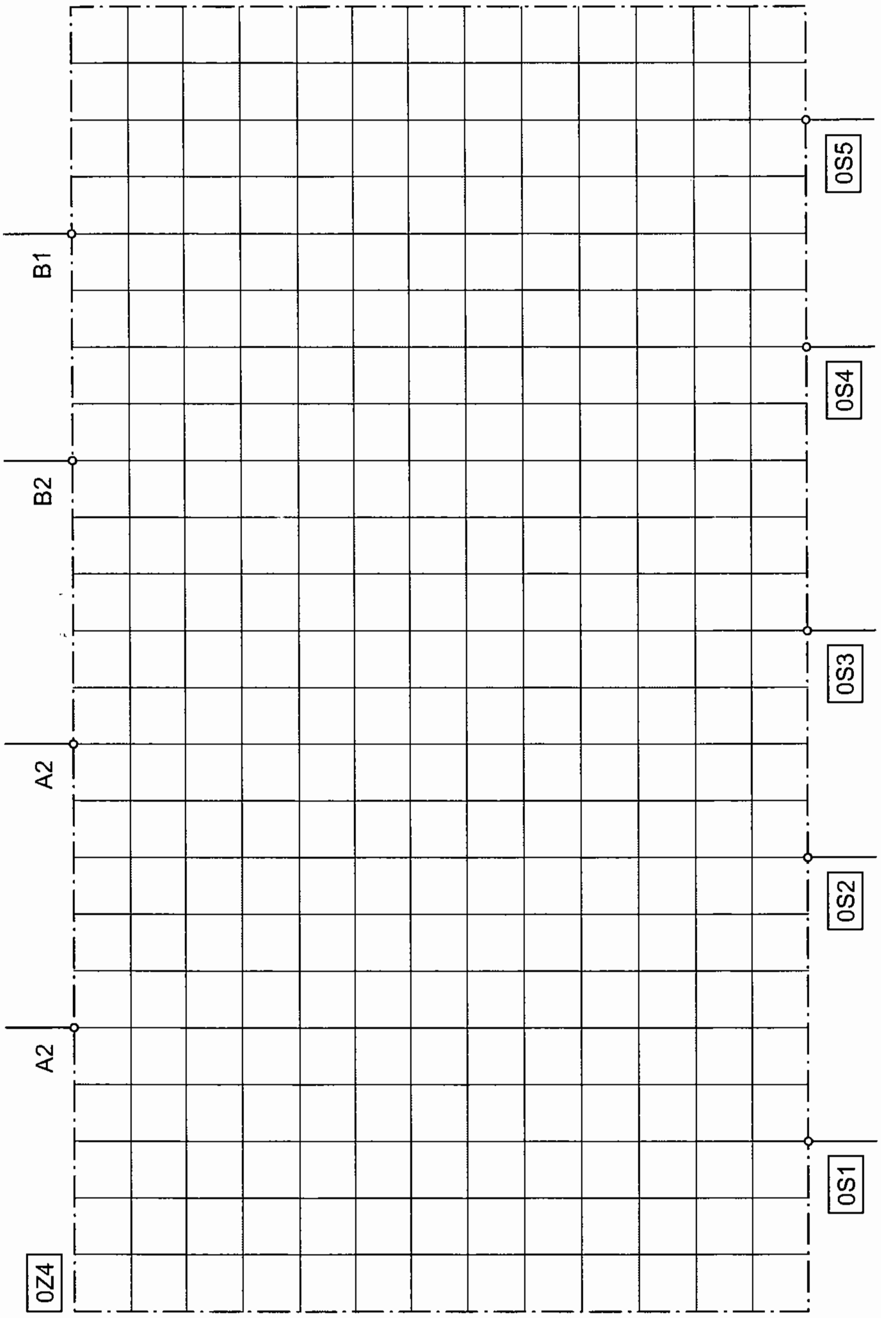


Fig. 20/3: Circuit diagram



Part B - Fundamentals

The theoretical fundamentals for the training package Pneumatics - advanced level can be found in the textbook:

Learning System for Automation and Technology

Fundamentals of pneumatic control technology

FESTO

Part C – Solutions

Scaled up circuit diagrams have been drawn up for exercises 12 to 16 as well as 18, and added to the solutions.

Furnace door control

Notes on procedure

- The complete control is made up of just five valves and one actuator. Despite this fact, we recommend that you start labelling the components at this stage, for example the cylinder should be labelled (1A) and the push button (1S1). This can be done with a soft pencil or self-adhesive labels without damaging the components. In the case of more extensive circuits, the individual valves should be identified in accordance with the circuit diagram. If this is not done, fault finding is made considerably more difficult; in the case of an extensive control system, it becomes almost impossible.
- Observe the direction of movement during opening and closing. When the cylinder extends, the furnace door closes and vice-versa.
- The control signal from valve (1S1) only lasts a short time. Valves (1V1) and (1V2) accordingly react only briefly to the acknowledgement of the control pressures (1V4) and (1V3), so that these become depressurised and can then be reactivated.
- The control signal for (1V4) is the back pressure, which arises when the cylinder travels into the end positions: a signal is either produced via (1V1), (1V3) to (1V4) -"retract"- or via (1V2), (1V3) to (1V4) -"extend"-.
- We recommend that the control system is operated at a pressure of p = 4 bar (400 kPa).
- The convertible 3/2-way pneumatic valves are to be used as components (1V1) and (1V2). These valves are supplied in the normally closed position. The valves are to be converted to normally open position by interchanging the blanking plug and working port.

  Alternatively, 5/2-way pneumatic valves may also be used, in which case working port 4 must be plugged. In addition, a T-piece (quick push-pull distributor) and short piece of tubing are to be attached to the valve. The remaining two connections of the T-piece are to be connected together by means of a short piece of tubing.
- As in the case of Basic Level TP101, each circuit requires a start-up valve together with filter regulator and a manifold (see circuit design).

Components list

Components	*Quantity*	*Designation*
1A	1	Double-acting cylinder
1V1, 1V2	2	3/2-way pneumatic valve, convertible
1V3, 1V4	2	5/2-way double pilot valve
1S1	1	3/2-way valve with push button, normally closed
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	6	Push-in T-connector

Components (0Z1) and (0Z2) are shown in the circuit design, but not in the circuit diagram.

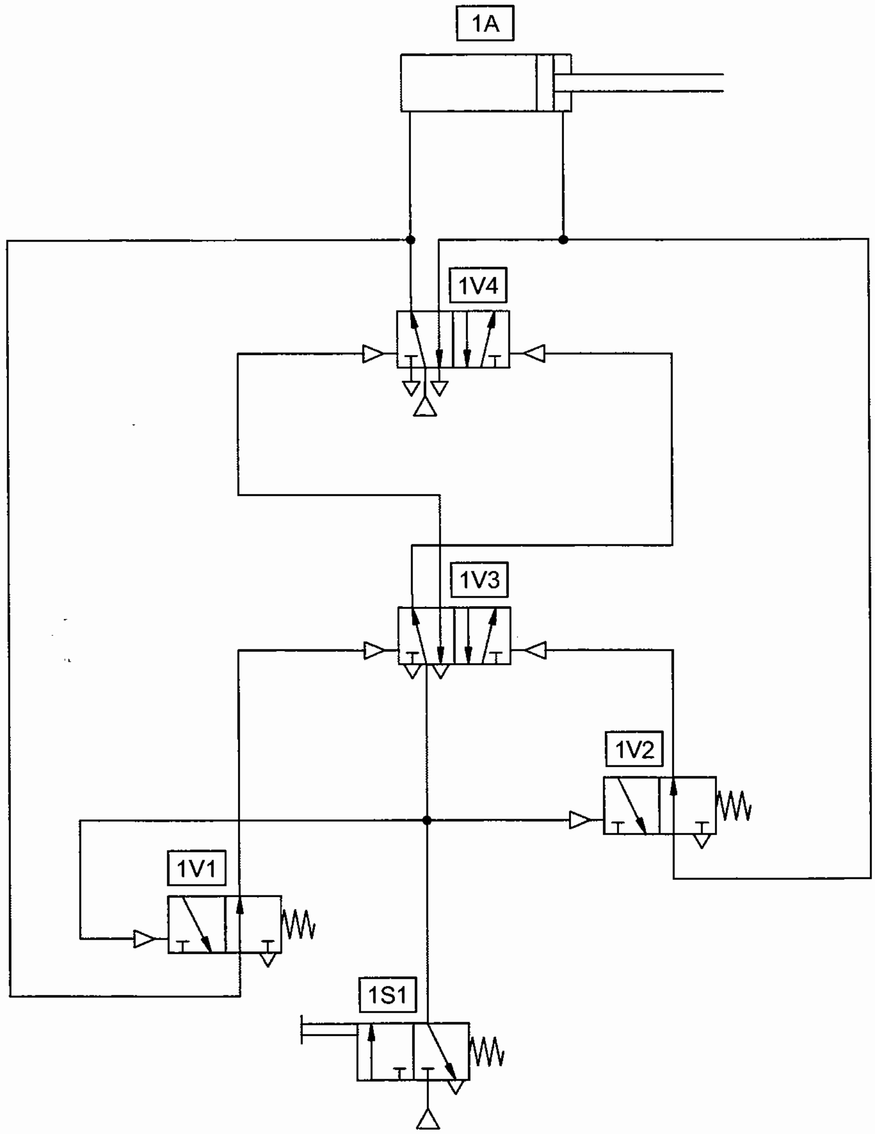
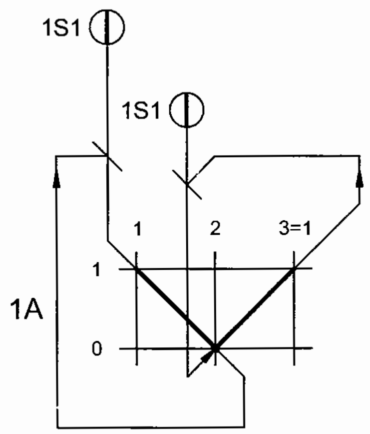


Fig. 1/2: Circuit diagram

Fig. 1/3:
Displacement-step diagram



Solution description

Initial position

The furnace door is closed. The piston rod of the cylinder (1A) is extended. The 5/2-way double pilot valve (1V4) supplies the piston area with air and the piston rod area is exhausted. The control valve (1V3) is still switched to flow from 1-4.

Step 1-2 – open furnace door.

If the 3/2-way valve (1S1) is actuated, the 3/2-way pneumatic valves (1V1) and (1V2) are exhausted simultaneously. Therefore, the control air can pressurise the pilot side 12 of the final control element (1V4) via ports 1 and 4 of the valve (1V3). Valve (1V4) reverses. The piston rod side of the cylinder (1A) is pressurised. The piston travels into its retracted end position. At the same time, reversing valve (1V3) is switched by the air via the 3/2-way double pilot valve (1V2) so that the final control element (1V4) can be reversed when a new start signal is given.

Step 2-3 – close furnace door.

If the push button (1S1) is pressed again, the control air flows via ports 1 - 2 of the control valve (1V3) to the control side 14 of the final control element (1V4). The cylinder is pressurised on the piston side and the piston rod extends. At the same time, the control valve (1V3) is brought into its lefthand switching position via the 3/2-way pneumatic valve (1V1). The control system is once again in the defined initial position drawn. Another start signal will now open the furnace door once again.

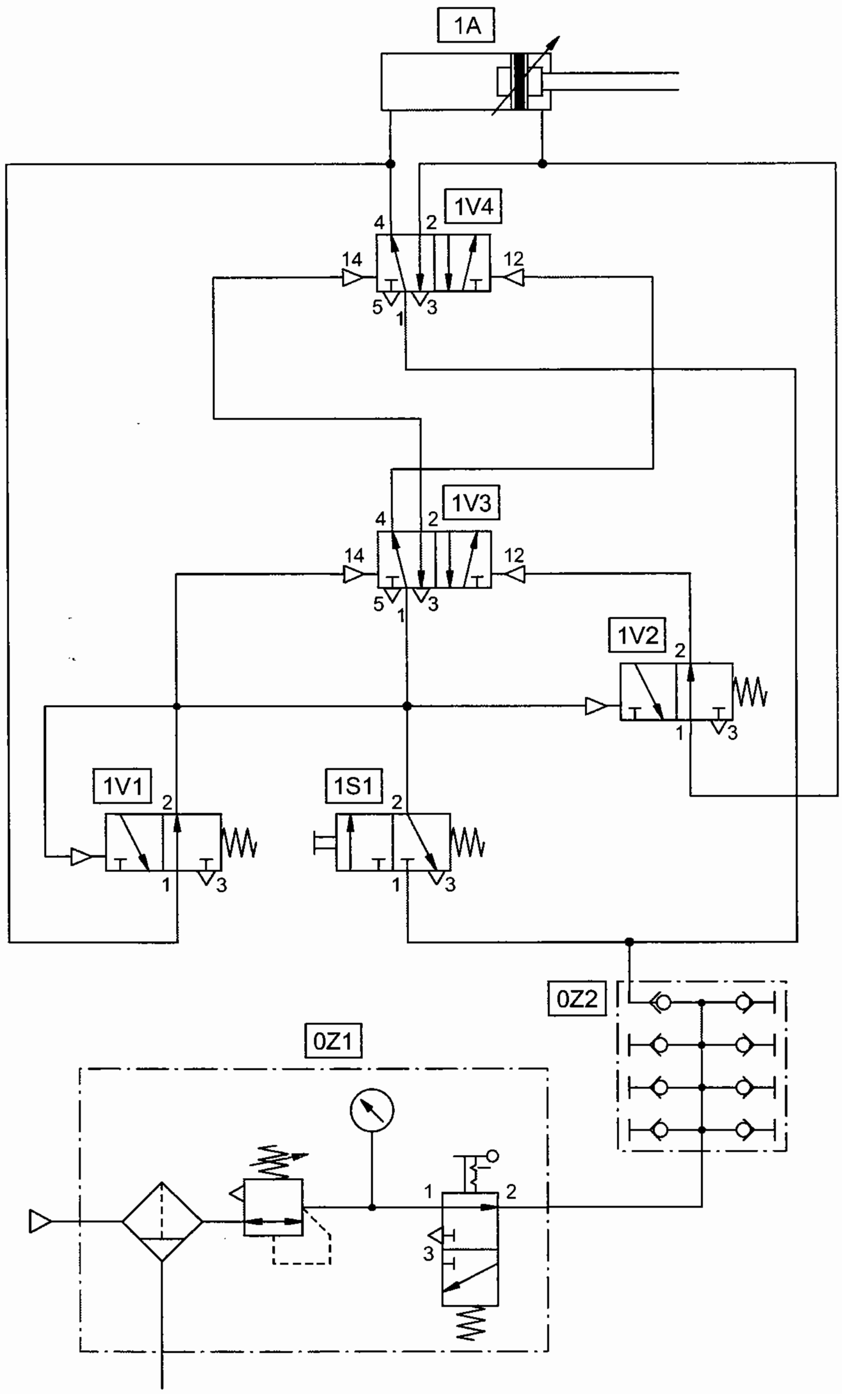


Fig. 1/4:
Circuit design

Further development

- Extend the displacement-step diagram into a function diagram showing all components (valves).
- Develop a circuit with the same function, where the end positions are checked by roller lever valves.

Vertical step feeder

Notes on procedure

- In reality, the two cylinders are linked by a cord thus creating a positive mechanical drive. When the circuit is built on the profile plate, this positive drive is simulated by four one-way flow control valves (exhaust air flow control on both sides) of the cylinder.
- The convertible 3/2-way pneumatic valve is to be used as component (0V2). This valve is supplied in the normally closed position and is to be converted to normally open position by interchanging the blanking plug and working port. Alternatively, a 5/2-way pneumatic valve may also be used, in which case working port 4 must be plugged. In addition, a T-piece (quick push-pull connector) and short piece of tubing are to be attached to the valve. The remaining two connections of the T-piece are to be connected together by means of a short piece of tubing.
- Latching must be checked on the program selector switch (0S1) and identified. The correct position is set for program I (double stroke), if pressure arises at 2.
- The pneumatic preselect counter (0V3) is set whilst the black key (left) is continuously pressed and the digit positions (ones, tens ....) are entered.
- Pneumatic flow control valves, in this case, one-way flow control valves, have a wide setting range (approx. 12 rotations) owing to the fine threaded regulating screw. The setting can be fixed with the lock nut (width across flats 8 mm) .
- Should the installation stop from time to time, check whether the counter is at "0000". If so, enter 10 operating cycle once again (or preferably 30, since the observation period will be longer) using the black switch on the counter (0V3).

Solution 2

Components list

Components	*Quantity*	*Designation*
1A, 2A	2	Double-acting cylinder
0V2	1	3/2-way pneumatic valve, convertible
0V4, 1V2, 2V1	3	5/2-way double pilot valve
1V1	1	Shuttle valve
1V3, 1V4, 2V2, 2V3	4	One-way flow control valve
0S2	1	3/2-way valve with push button, normally closed
0S1	1	5/2-way valve with selector switch
1S1, 2S1	2	3/2-way roller lever valve, normally closed
0V3	1	Pneumatic preselect counter
0V1	1	Time delay valve, normally open
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	6	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 2/2: Circuit diagram

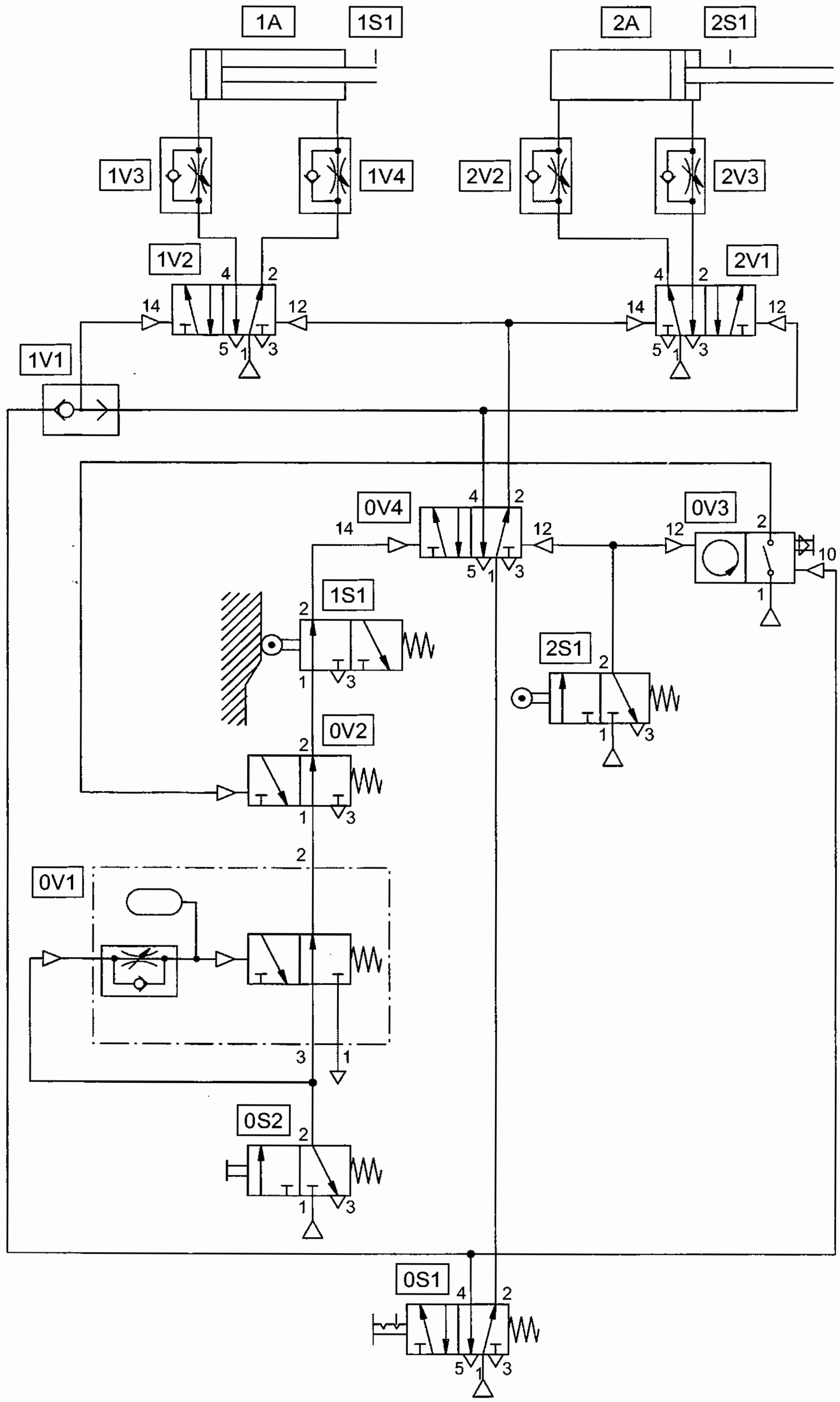
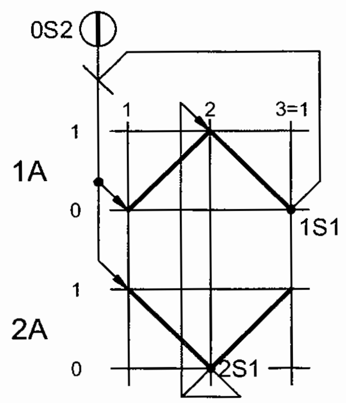
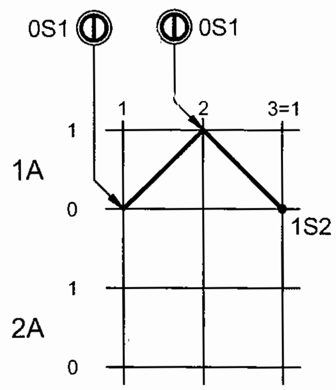


Fig. 2/3: Displacement-step diagram





Solution description

Initial position

Cylinder (1A) is in the retracted end position. Cylinder (2A) assumes the forward end position. Roller lever valve (1S1) is actuated. Subtracting counter (0V3) is set to 10 double strokes. 5/2-way valve (0S1) is latched to flow from 1-2.

Program I: Lifting the suspended basket.

By actuating the start button (0S2), the control valve (0V4) is switched to flow from 1-4. The start signal can pass through the following valves unhindered:

(0V1) Time-delay valve with normally open position
(0V2) 3/2-way valve with normally open position and spring return
(1S1) 3/2-way roller lever valve, in actuated position.

After a brief adjustable period of time, the start signal is switched off again by the time delay valve (0V1). Thus, it is ensured that only one double stroke can take place even when the start button (0S2) is held down for a long time (circuit for signal shortening). The control element (0V4) simultaneously switches the final control element (1V2) to flow 1-4, cylinder (1A) extends, and the final control element (2V1) to flow from 1-2, cylinder (2A) retracts. The piston rod of the cylinder (2A) actuates the roller lever valve (2S1) in its retracted end position. Valve (0V4) is reversed. The two cylinders return to their initial positions.

A further start signal enables the next double stroke to be executed. The roller lever valve (2S1) also passes a counting signal to the subtracting counter (0V3). After 10 doubles strokes, this reverses the valve (0V2). Actuation of the start button (0S2) can no longer set the actuators in operation.

Program II: Lowering the suspended basket.

If valve (0S1) is actuated and flow from 1-4 latched, the counter (0V3) is reset. Valve (0V2) returns to the normally open position again. The same signal switches final control element (1V2) to flow 1-4 and cylinder (1A) extends.

The roller lever (1S1) is no longer operated. This prevents the piston extending a second time if an early signal via the start button (0S2) is present.

Only when valve (0S1) is reset, can the signal from output 2 reverse the final control element (1V2). Cylinder (1A) retracts.

Solution 2

Transferring of billets

Notes on procedure

- The convertible 3/2-way valve is to be used for component (1V2). This valve is supplied in the normally closed position. It is to be converted to normally open position by interchanging the blanking plug and the working port.
  Alternatively, a 5/2-way pneumatic valve may be used, in which case working port 4 must be plugged, providing flow from 1 – 2 when not operated. In addition, a T-piece (quick-push-pull distributor) and a short piece of tubing are to be attached to the valve. The remaining two connections of the T-piece are to be connected together by means of a short piece of tubing.
- The final control element (2V2) is obtained by converting using a 5/2-way valve with the output 2 plugged.
- The control line between the adjustable vacuum actuator (1V1) and the actuator (2A) is formed using a T-piece (quick push-pull connector).
- The vacuum generator (2A) works according to the ejector principle (Venturi effect).
- The pressure level for the vacuum generator must be adapted to the practical circumstances (e.g. surface roughness of the object to be transported). With a supply pressure of p = 5 bar (500 kPa), an optimum balance between sound level, air consumption, vacuum strength and suction force is achieved.

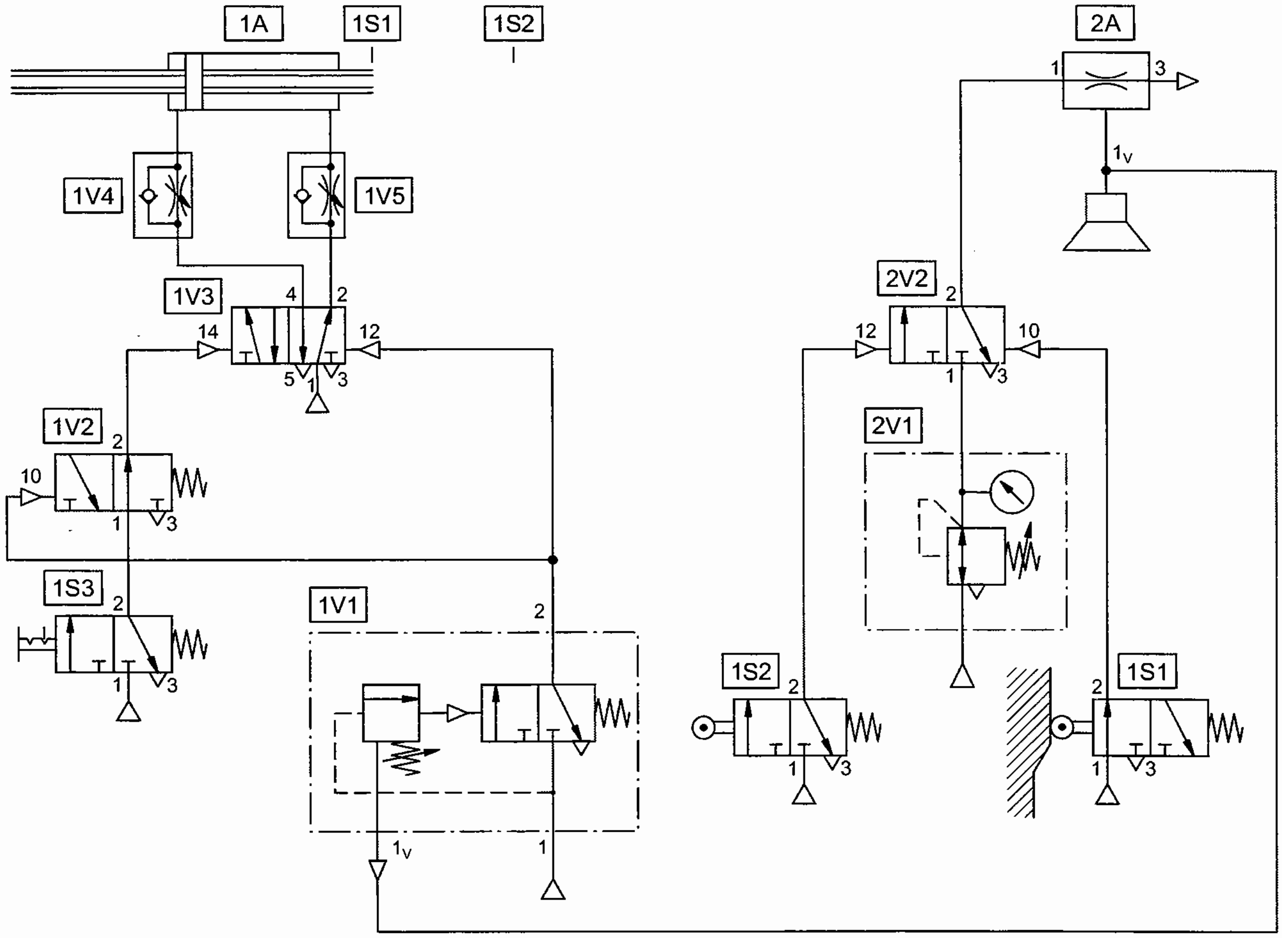
Component (1V1) is not a pressure sequence valve, but an adjustable vacuum actuator. The symbols, which are determined by function, are deceptively similar.

Components list

Components	*Quantity*	*Designation*
1A	1	Double-acting cylinder
2A	1	Vacuum generator/ suction cup
1V2	1	3/2-way pneumatic valve, convertible
1V3, 2V2	2	5/2-way double pilot valve
1V4, 1V5	2	One-way flow control valve
1S3	1	3/2-way valve with selector switch, normally closed
1S1, 1S2	2	3/2-way roller lever valve, normally closed
2V1	1	Pressure regulator with pressure gauge
1V1	1	Adjustable vacuum actuator
0Z2	1	Manifold, normally closed
0Z1	1	On-off valve with filter regulator
	6	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 3/2: Circuit diagram



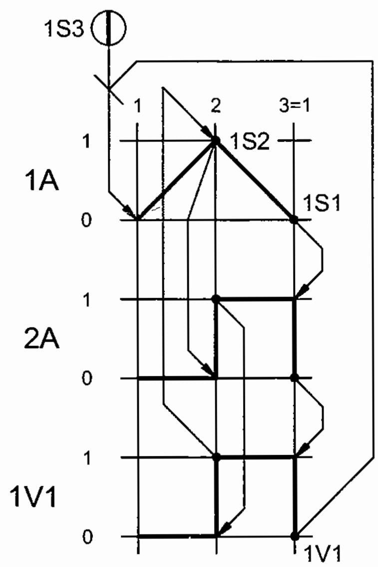


Fig. 3/3: Displacement-step diagram

Solution description

Initial position

In the normal position, the piston rod of the cylinder (1A) is retracted. Roller lever valve (1S1) is actuated. 3/2-way valve (2V2) is in the normally closed position, i.e. there is no flow to the suction nozzle (2A).

Continuous cycle

Suction pick up of billets

Once the start valve (1S3) has been manually latched, the final control element (1V3) reverses via port 14. This is possible since no signal is yet present at the 3/2-way normally open pneumatic valve with spring return (1V2). The piston rod extends with exhaust air throttled. In its forward end position, it actuates the roller lever valve (1S2). The resulting signal reverses the final control element (2V2)and air flows to the vacuum generator. The suction cup at the end of the piston rod is now able to pick up the billet.

Transferring billets

The adjustable vacuum actuator (1V1) is actuated via a vacuum connection line. Output 2 of the vacuum actuator supplies a one signal. This causes the 3/2-way valve (1V2) first of all to be switched via 10 and exhausted and then the continuous signal at port 14 of the final control element (1V3) to be switched off. Now the signal present at port 12 is able to reverse the final control element. The piston rod with suction cup and billet retracts. The roller lever (1S1) is actuated in the retracted end position. The final control element (2V2) now switches off the vacuum generator and the billet drops on to the conveyor belt. A vacuum is no longer present at the adjustable vacuum actuator (1V1). Its 3/2-way valve returns to the normally closed position. There is no longer a signal at the control port of the 3/2-way valve (1V2). The continuous signal of the start detent (1S3) is once again able to reverse the final control element (1V3). A new operating cycle begins.

Single cycle or end of cycle

If the start-up valve (1S3) is disengaged immediately after actuating, the final control element (1V3) will remain in its righthand switching position after one operating cycle. Thus, the actuator remains in its retracted end position, until a new start signal reverses the final control element (1V3).

Further development

- Build some simple faults into the control system, (e.g. roller lever valve not fully actuated, tubing kinked , mixing up of valve connections.
- The extent of fault finding depends on the time remaining and on the perceptiveness of the trainees. It is carried out with the help of the displacement-step diagram (function diagram).
- Extend the displacement-step diagram into a function diagram for all components.
- Redesign the control making use of the stepper module.

Solution 3

Drilling of wooden cubes

Notes on procedure

- The pneumatic feed units with hydraulic cushioning cylinder are replaced by two double-acting cylinders with exhaust air restriction on both sides for practical construction on the assembly board. However, please note that in practice it is only possible to achieve an even feed for maching workpieces using hydraulic cushioning cylinders.
- The START button (1S3) may only be pressed down briefly. If it is still actuated when the switching cam of the actuator (1A) approaches the back pressure valve (1S2), the final control element (1V1) cannot be reversed. The control stops until the START button is released. Therefore, there is a danger that the switching cam of the actuator (1A) will push the back pressure valve (1S2) out of its mounting if it is not precisely adjusted.
- It is very important that the back pressure valve (1S2) is correctly adjusted. It can be readjusted by loosening the lock nut or by twisting the switching cam of the piston rod.
- The magnetically actuated pneumatic signal generator (2S2), a proximity switch, is activated by the magnetic field of the piston. The proximity switch must be placed flat against the cylinder barrel and secured. Manual movement of the piston rod for cylinder position adjustment is easier if the cylinder is unpressurised whilst the proximity switch remains pressurised.
- The 3/2-roller lever valve with idle return (1S1) should be positioned under the piston rod (1A) on the profile plate so that a switching signal is produced shortly before the retracted end position is reached. (provided that the piston rod extends to the right when facing the profile plate from the front.) When the retracted end position has been reached, the roller lever valve with idle return is no longer activated so that the final control element (2V1) can be reversed via the valve (2S2).
- The roller lever valve (2S1) is activated in the retracted end position via the switching cam of the actuator (2A). In this system circuit diagram, the signal generator (2S1) above the end of the piston rod is shown symbolically by a short line. The proximity switch (2S2), which is switched contactlessly in the forward end position, is shown symbolically in the system circuit diagram to the left of this. This may be slightly confusing to the trainee.

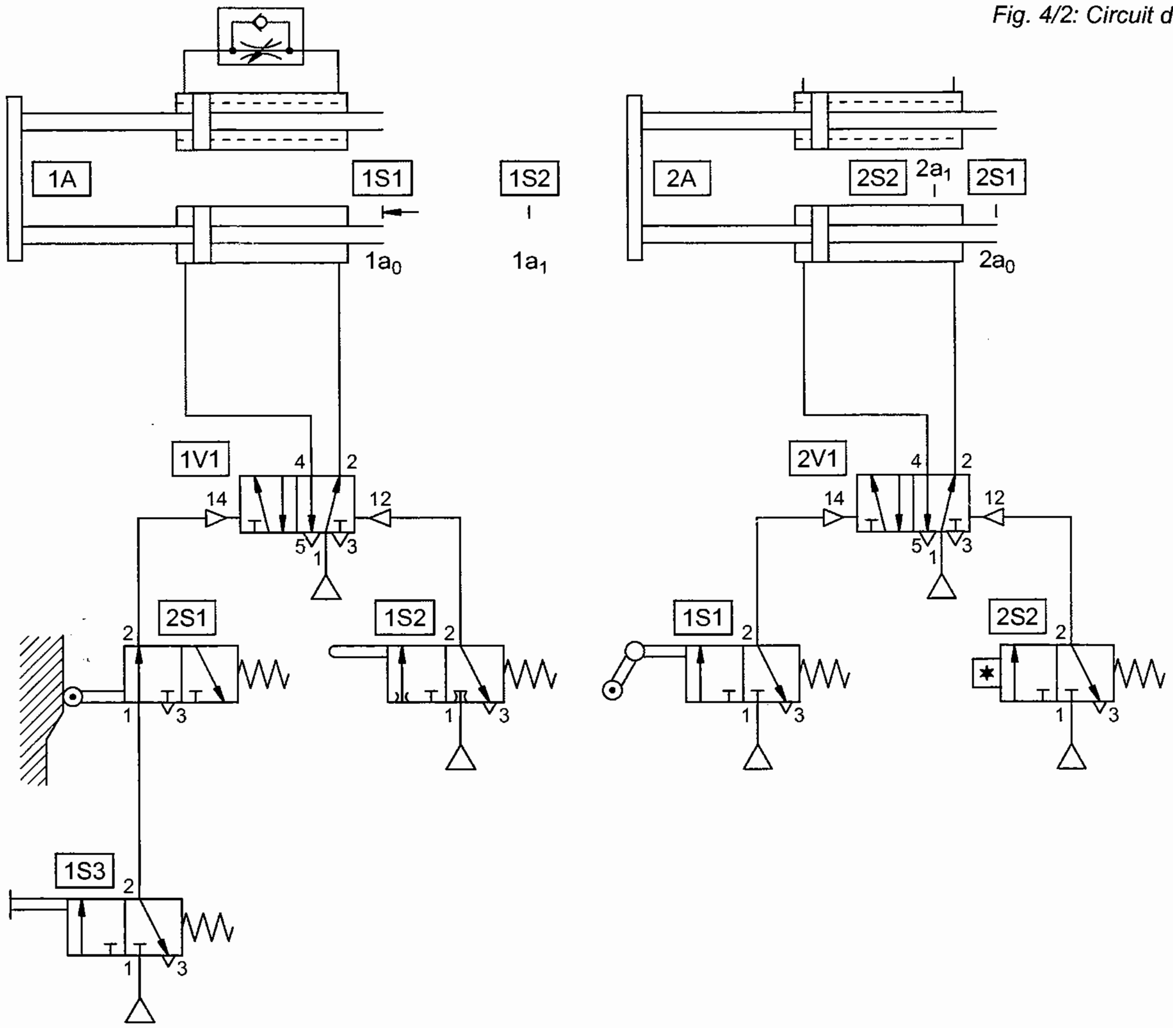
Solution 4

Components list

Components	*Quantity*	*Designation*
1A, 2A	2	Double-acting cylinder
1V1, 2V1	2	5/2-way double pilot valve
1V2, 1V3 2V2, 2V3	4	One-way flow control valve
1S1	1	3/2-way roller lever valve with idle return, normally closed
1S2	1	Back pressure valve
1S3	1	3/2-way valve with detent switch, normally closed
2S1	1	3/2-way roller lever valve, normally closed
2S2	1	Pneumatic proximity switch
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	6	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 4/2: Circuit diagram



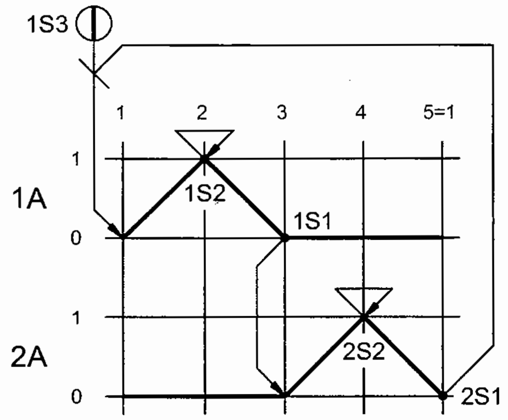


Fig. 4/3: Displacement-step diagram

Solution description

In this exercise, the end position of the actuators is checked by four different sensors.

Actuator (1A)	Retracted end position	$1a_0$:	3/2-way roller lever valve with idle return (1S1)
	forward end position	$1a_1$:	back pressure valve (1S2)
Actuator (2A)	retracted end position	$2a_0$:	roller lever valve (2S1)
	forward end position	$2a_1$:	pneumatic proximity switch (2S2)

Initial position

Actuators (1A) and (2A) are located in the retracted end position. The roller lever valve (2S1) is actuated. The switching cam of the actuator (1A) travels across the roller lever valve with idle return (1S1), which is therefore not actuated. The final control elements (1V1) and (2V1) assume the switching position with flow from 1-2.

Drilling with vertical feed unit

When the START button (1S3) is pressed, the final control element (1V1) is reversed via the switched roller lever valve (2S1). The piston rod of the actuator (1A) extends. The back pressure valve (1S2) is actuated in the forward end position. The final control element (1V1) is reversed again. The actuator (1A) retracts.

Drilling with horizontal feed unit

Shortly before reaching the retracted end position, the actuator (1A) travels over the roller lever valve with idle return (1S1). A signal is generated, which causes the final control element of the feed unit (2V1) to switch to flow from 1-4. The piston rod of the actuator (2A) extends. Thus, there is no danger of the feed units colliding. When the actuator (2A) reaches its forward end position, it actuates the pneumatic proximity switch (2S2). This sends a signal to the final control element (2V1). The piston rod of the actuator (2A) retracts and actuates the START latch (2S1). Only then is it possible to start a new cycle via a renewed manual start signal.

Further development

- Extend the displacement-step diagram by adding the signal, control and final control elements.
- Ask the trainees to introduce deliberate faults into each others fully constructed, functional control systems and then to carry out fault finding and to discuss this; e.g.:
  - replace roller lever valve with idle return (1S1) with roller lever valve
  - exchange the ports of the final control elements.

  Modify the circuit so that movements 1A– and 2A+ start simultaneously.

  Abbreviated notation

  1A+ 1A– 2A–
  2A+
- Design the control system without roller lever valve with idle return. Use the stepper module. This control system can also be realised using reversing valve technology (see exercise 16 – 19 - Basic Level).

Filling of medicine bottles

1.Sequencer

Notes on procedure

- The Festo Didactic sequencer, with 4 stepper modules is used here for the first time. Stepper module technology has undenied advantages over reversing valve technology (cascade controls) and the use of roller lever valves with idle return:
  - low development costs (circuit diagram)
  - simplified reading and understanding of the circuit diagram (Black box principle)
  - minimal tubing (shorter assembly time)
  - marginal conditions are easier to realise
  - minimal cost when modifying a control
  - greater operational reliability
  - simplified monitoring thanks to visual indicator and manual override.

  However:
  A new system of circuitry also calls for a new method of fault finding.

  Basically, the following principle applies:
  Once the sequencer (processor) has been checked and has switched through correctly, you can rely on it. Problem areas are more likely to be the push buttons, switches and sensors and possibly also the tubing connections (e.g. fractured tubing)

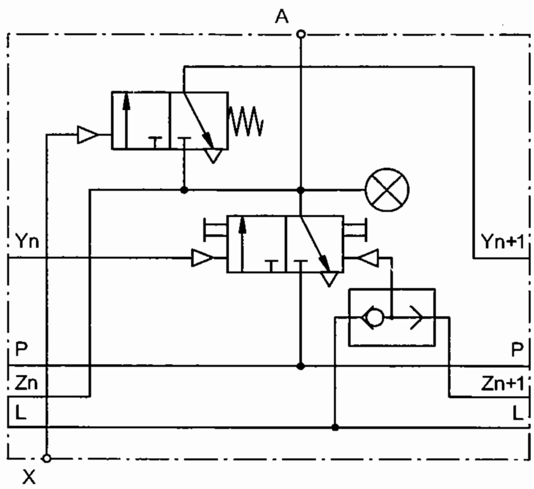
2. Stepper module

- The individual stepper module type TAA performs three tasks:
  - switching through (relaying) the signals from input X to output A
  - preparing (subsequent step)
  - clearing (preceding step).

2.1 Module TAA

Compare this description with the circuit diagram and the sketch. This module is made up of three valves. A 3/2-way valve pressurised on one side acting as an AND gat (top left), a double piloted 3/2-way valve as the memory (in the centre) and the OR gate (bottom right). In addition, a network of vertical and horizontal connections.

Fig. 5/2: Module TAA



X: input (from the signalling element)
A: output (to a signalling element, to the actuator)
P: compressed air supply
Y: to “set” the memory - flow P to A
Z: to “reset” the memory - pressure relief from P to A
L: to RESET the stepper sequencer (4 modules)

2.2 Mode of operation of module TAA

- The memory is set by a signal from the preceding module. This causes a signal to be sent to A, which activates the final control element and thus the actuator.
- The actuator signals via a sensor (signal element) at input X that a step has been completed.
- The signal at input X reverses the AND gate, which sets the memory of the following module via Yn+1 (pressure is supplied to the AND gate via P).
- Simultaneously to the signal at A, which comes from the memory, this signal is passed back via Zn and the OR gate to the previous memory and resets it.
- The OR gate enables the sequencer to resume the initial position (signals at output A and Yn+1) in any situation (e.g. EMERGENCY-STOP).

2.3 Module TAB

Module TAB is similar to module TAA. The difference is in the construction of the OR gate, which must always be the last module in any sequencer chain.

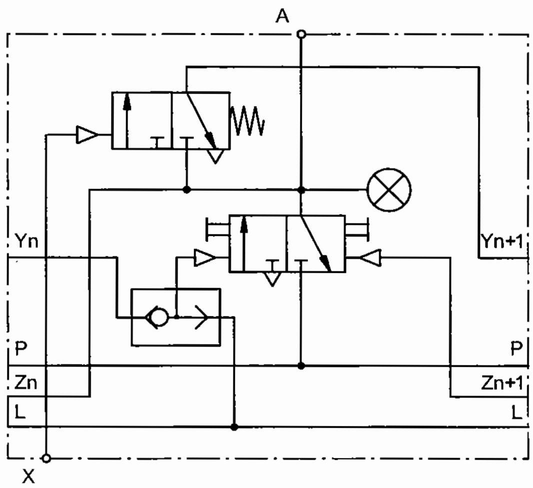


Fig. 5/3:
Module TAB

2.4 Mode of operation of module TAB

- There must always be flow to A in the previous memory in the initial position and it must be set so that via the AND gate of this module and Yn+1 a continuous pulse for renewed setting of the first memory is present at the dual-pressure valve switched ahead of the sequencer.
- If, together with the start pulse, the first memory is via the dual-pressure valve, then the previous memory is reset via zn+1, i.e. it is ready to take over the final step of the new operating cycle.

2.5 Module TAC

Module Type TAC has no memory (economy module). It does not form part of equipment set TP102 and is not described here.

2.6 There are two different stepper modules in equipment set TP102.

Type TAA/TAB: 3 TAA modules and 1 TAB module
This type must always be used.

Type TAA: 4 TAA modules, extension
This type can only act as an extension to the previous type and must be switched ahead of this.

The various types are recognised by looking at the identification code in the black holes on the output side.

**2.7 Checking the stepper module.
Be sure to connect up correctly**

Supply air: P
Connect: Yn to Yn+1
Connect: Zn to Zn+1
Connect: A1 to X1; A2 to X2; ...

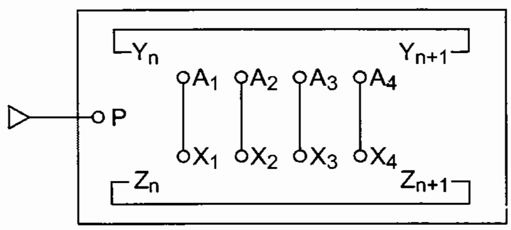


Fig. 5/4:

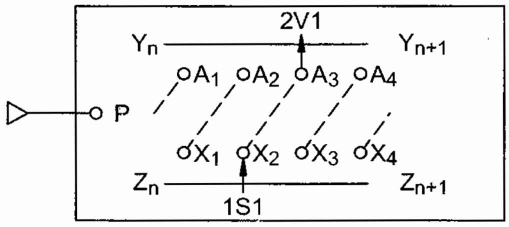
If the module is working, it "ticks" through for as long as you continue to apply pressure at P. It can be clearly seen how the white sliding indicators (manual override) shift between X and A. Each shift means: "step complete". The white pins, bottom left of the black base, signal "no pressure".

You see, it's all quite simple!

2.8 Checking the individual steps

Example for step 3:
Roller level valve (1S1) supplies a signal to the second stage of the sequencer, which passes on the signal to the final control element (2V1) so that the cylinder (2A) retracts.

Fig. 5/5:



2.9 Checking the complete circuit

The complete circuit is checked by first disconnecting all "A" connections, then waiting for each continuation pulse (first A1, then A2...), connecting with the respective line, thus running through the entire cycle step-by-step.

3. Assembly and adjustment of proximity switches (2S1) and (2S2)

- Using mounting kit on the right and lefthand side of the cylinder barrel, connection nipple on the inside.
- Do not attach the proximity switches too far from the cylinder barrel otherwise they will not be switched by the magnet on the cylinder piston.
- The switching point can be determined precisely. Repetition accuracy +/– 0.2 mm. Accurate adjustment, however, requires practice.
- If (2A) is heavily throttled, (1A) starts with the advance stroke before (2A) has reached its end position.
- A pressure of 4 bar is better than 3 bar as otherwise the stick-slip effect occurs.
- Roller lever valves (1S1) and (1S2) must be installed so that they switch reliably. This can be checked via the A ports of the stepper module.
- The latching of the start valve (0S1) determines whether one cycle (single cycle) or a continuous operation (continuous cycle) is operational. Label as to which of these it is (using a soft pencil or self-adhesive labels).

Components list

Components	*Quantity*	*Designation*
1A, 2A	2	Double-acting cylinder
0V1	1	Dual-pressure valve
1V1, 2V1	2	5/2-way double pilot valve
1V2, 1V3, 2V2, 2V3	4	One-way flow control valve
0S1	1	3/2-way valve with selector switch, normally closed
1S1, 1S2	2	3/2-way roller lever valve, normally closed
2S1, 2S2	2	Pneumatic proximity switch
0Z3	1	Stepper module
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	6	Push-in T-connector

Components (0Z1) und (0Z2) are not shown in the circuit diagram.

Fig. 5/6: Circuit diagram

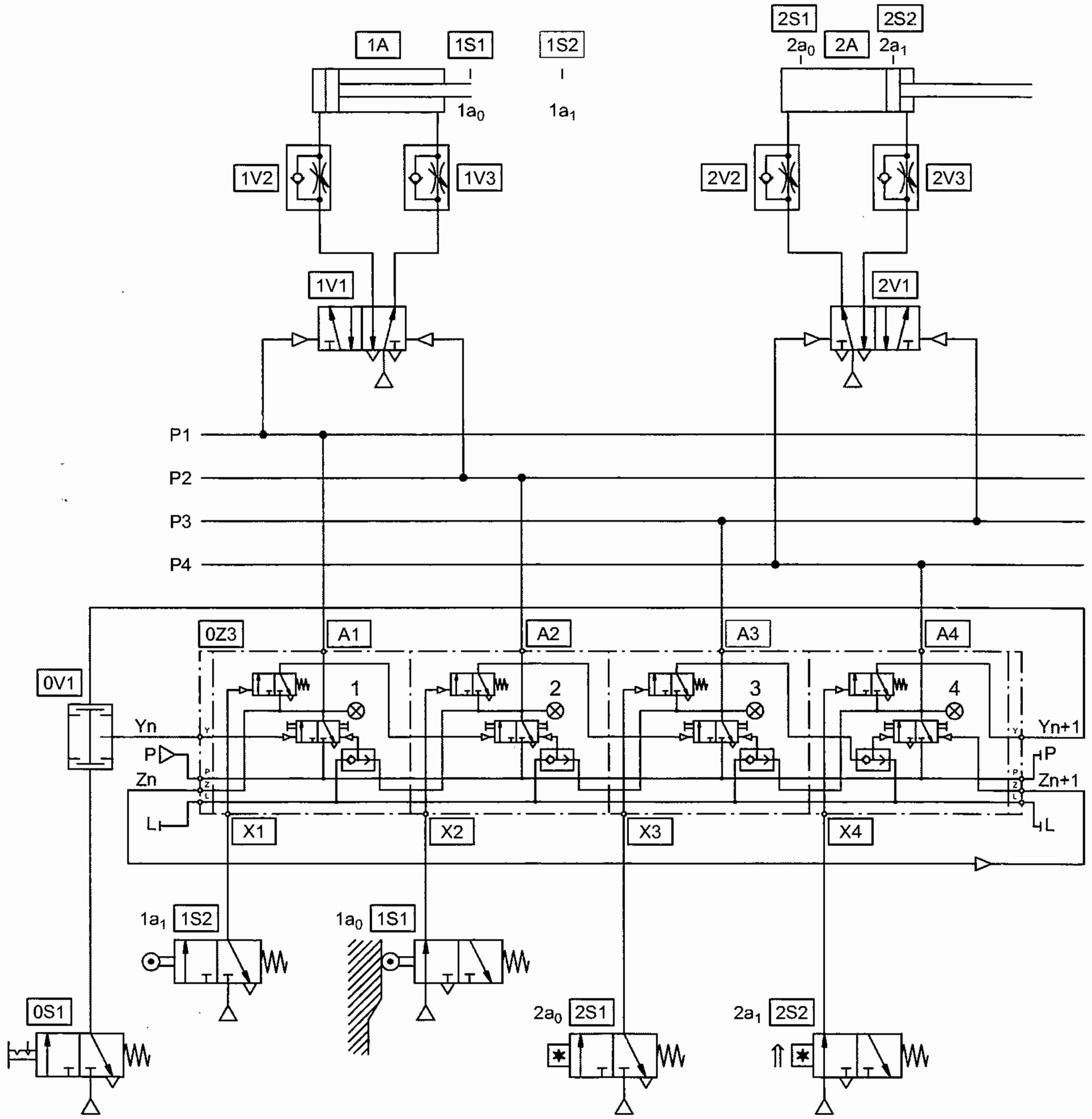
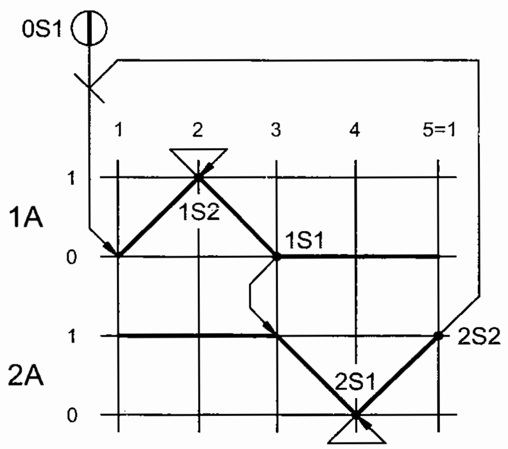


Fig. 5/7: Displacement-step diagram



Solution description for the circuit diagram

Initial position

The cylinder (1A) assumes the retracted end position, the piston rod of the cylinder (2A) is extended. The roller lever valve (1S1) is actuated. The pneumatic proximity switch (2S2) is switched through by the permanent magnet on the cylinder piston. Thus, there is a signal at input X4 of the sequencer. Output A4 is active. Yn+1 causes a signal to be present at the dual-pressure valve (0V1).

Filling bottles, cylinder (1A)

When the START valve (0S1) is actuated, the memory of the first module (type A) is set by the dual-pressure valve (0V1). Its output signal A1 reverses the final control element (1V1), and the cylinder (1A) extends. When it reaches its forward end position, it actuates the roller lever valve (1S2). As a result, the first module at X1 is pressurised. The spring returned 3/2-way valve (AND gate) is switched through and the memory is set on the subsequent second module (type A). The output signal A2 reverses the final control element (1V1). Cylinder (1A) returns to its retracted end position. The signal A2 also resets the first module of the memory valve. This can only be switched by a renewed start signal and output signal Yn+1.

Releasing bottles, cylinder (2A)

In its retracted end position, cylinder (1A) actuates roller lever valve (1S1). The resulting signal acknowledges the output signal A2 at X2 and switches the third module (type A). Output signal A3 reverses the final control element (2V1). Cylinder (2A) retracts. Proximity switch (2S1) acknowledges the movement and switches to the fourth module (type B) via X3. The signal A4 reverses the final control element (2V1) and cylinder (2A) extends. Proximity switch (2S2) acknowledges the end position of the cylinder via X4. The spring returned 3/2-way valve of the 4th module (type B) is switched. The signal Yn + 1 is once again present at the dual pressure valve (0V1).

Single cycle

If the START valve (0S1) is only briefly actuated, i.e. is not latched to continuous cycle, only signal Yn+1 is present at the dual-pressure valve (0V1) at the end of the cycle. A new cycle can only be started by actuating the START valve.

Continuous cycle

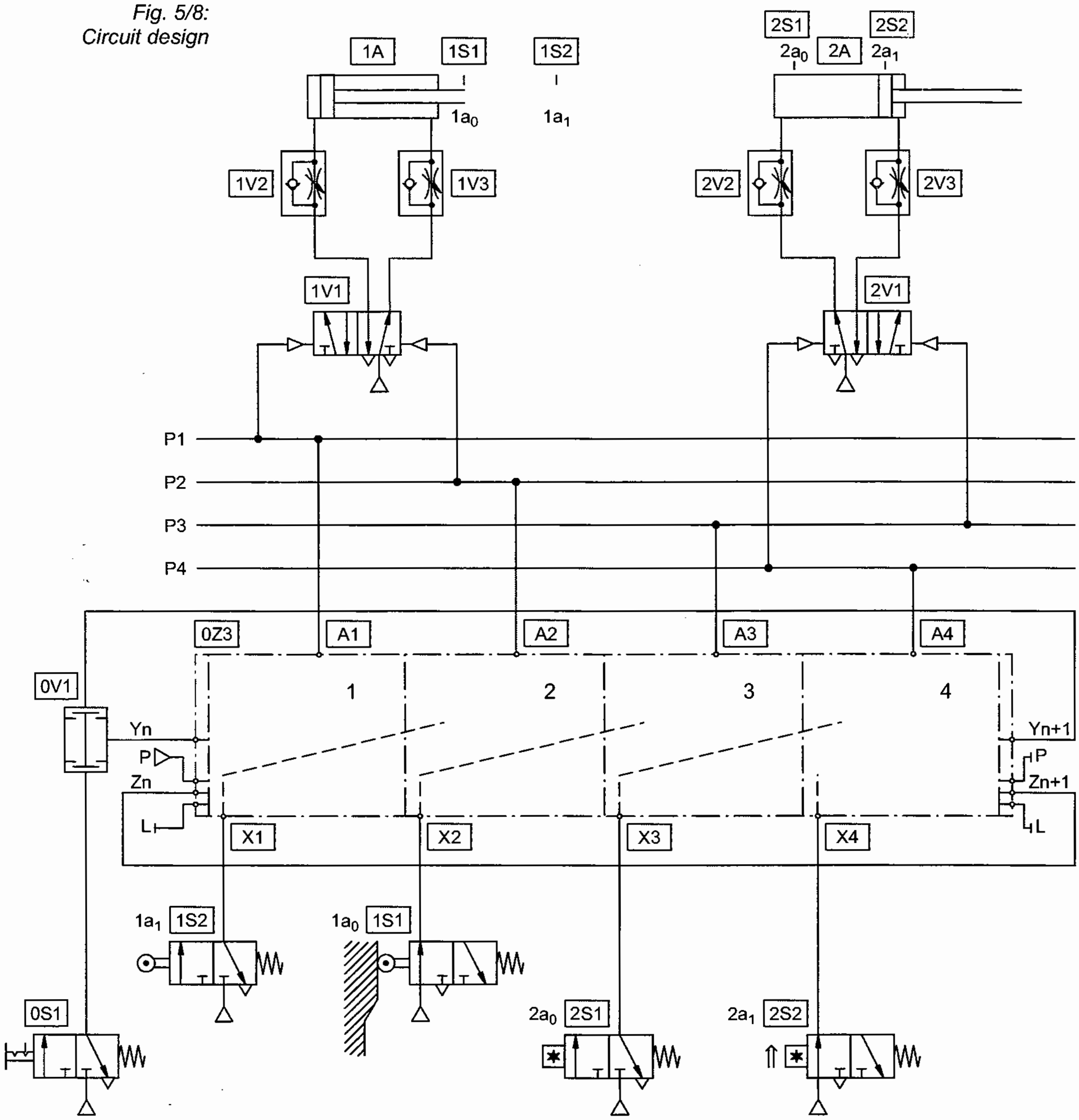
If the START valve (0S1) is detented, a continuous signal is present at the lower input of the dual-pressure valve (0V1). A new cycle starts automatically when the initial position of the actuators is signalled via connection Yn+1 of the fourth stepper module (type B).

End of cycle

Unlatching the START valve (0S1).

Solution 5

Fig. 5/8:
Circuit design



Simplified solution description for the circuit design

Filling bottles, cylinder (1A)

When the START button (0S1) is pressed, the output signal A1 is produced via (0V1), which reverses (1V1) via connection 14. Cylinder (1A) extends and via (1S2) produces output signal A2 through input X1. (1V1) reverses, cylinder (1A) retracts and actuates (1S1). A signal is present at input X2.

Releasing bottles, cylinder (2A)

Signal at X2 produces output A3. (2V1) reverses; cylinder (2A) retracts and actuates (2S1). (2S1) produces X3 and thus A4. (2V1) reverses, cylinder (2A) extends and actuates (2S2). (2S2) produces X4 and Yn+1. Component (0V1) is pressurised on one side.

Further development

- Remove the dual pressure valve (0V1) from the control system. Connect up in such a way that all functions are maintained.
- Modify the sequencer tubing connections to produce the following motion sequences:

  Abbreviated notation:

  1. 1A+ 1A– 2A+ 2A–
  2. 1A+ 2A+ 2A– 1A–
  3. 1A+ 2A+ 1A– 2A–

  Which of these three motions sequences can be achieved without a sequencer (without reversing or roller lever valve with idle return) and why?
  Note: Outputs 2 of the valves (1S1), (1S2), (2S1) and (2S2) act directly on the final control elements (1V1) and (2V1).

The sequencer also permits fast conversion and adaptation to other hard-wired programmed control systems and motion sequences. In some cases, this may mean lower costs than in the case of a program modification for programmable logic controllers (PLC).

Feeding device for electro-plating bath

Notes on procedure

1. Components used

- The rodless cylinder has a ring magnet fitted to the piston, which pulls the outer slide along with it. This is also known as a pneumatic linear drive.
- The two one-way flow control valves (1V3) and (1V4) will not be required for the purpose of the practical circuit construction as the linear drive (1A) is already equipped with two one-way flow control valves.
- The magnetic piston also activates the proximity sensors (1S1) and (1S2).
- Time delays (t_1 = 5 sec; t_2 = 4 sec) have been designated. Component (0V1) is the already familiar normally closed time delay valve. Component (0V2) is a time delay valve with the positions interchanged, i.e. normally open. The output signal for this time delay valve must be inverted. This function is carried out by a normally open 3/2-way pneumatic valve (0V3).
- Valve (0S1) enables a shift between AUTOMATIC and MANUAL. Label this component. "MAN" in conjunction with the actuation of the valve (0S3) causes the sequencer and the actuators to be reset, i.e. all valves and cylinders assume the initial position. "AUTO" with actuation of the START button (0S2) generates the automatic sequence of a cycle (single cycle).
- The time delays can be shortened (interrupted) via the push buttons (0S4) (bath immersion time) and (0S5) (drain time).

2. Assembly:

- The following normally applies: Actuation produces a signal. The increased number of operating functions (push button, detent) in the following exercises may be confusing, therefore we would like to repeat the following recommendation:

  Make a note of the valve tasks - e.g. START, RESET, Bath immersion interruption, ... - and positions , e.g. MAN/AUTO, program I/II.

- To be absolutely certain, check each device to determine its function.
- Select the correct pressure! Piloted valves do not switch reliably until a pressure of p = 2.5 bar (250 kPa) is attained.
- Proximity switches (1S1) and (1S2) must be checked to determine whether connection 1 switches to connection 2; this is done by shifting the slide (1A). 1 = long connection, 2 = short connection.
- Sequencer: Don't forget the connection from Zn to Zn+1 and the P connection.

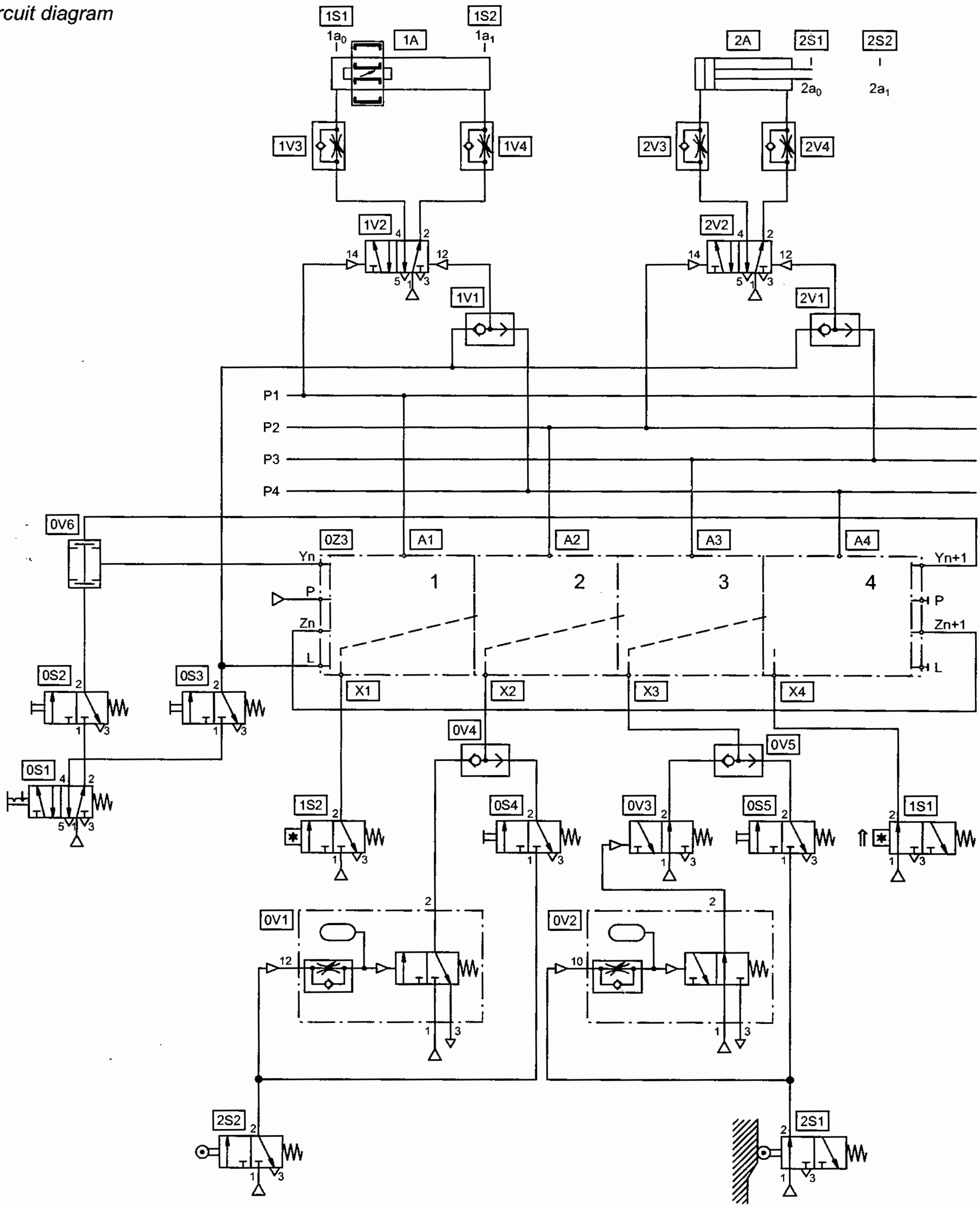
Components list

Components	*Quantity*	*Designation*
1A	1	Linear drive, pneumatic
2A	1	Double-acting cylinder
2V3, 2V4	2	One-way flow control valve
1V2, 2V2	2	5/2-way double pilot valve
0V2	1	3/2-way pneumatic valve, convertible
0V4, 0V5, 1V1, 2V1	2	Shuttle valve, 3-fold
0V6	1	Dual-pressure valve
0S1	1	5/2-way valve with selector switch
2S1, 2S2	2	3/2-way roller lever valve, normally closed
1S1, 1S2	2	Pneumatic proximity switch
0S2, 0S3, 0S4, 0S5	4	3/2-way valve with push-button, normally closed
0V1, 0V2	2	Time delay valve, normally closed
0Z3	1	Stepper module
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	15	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Solution 6

Fig. 6/2: Circuit diagram



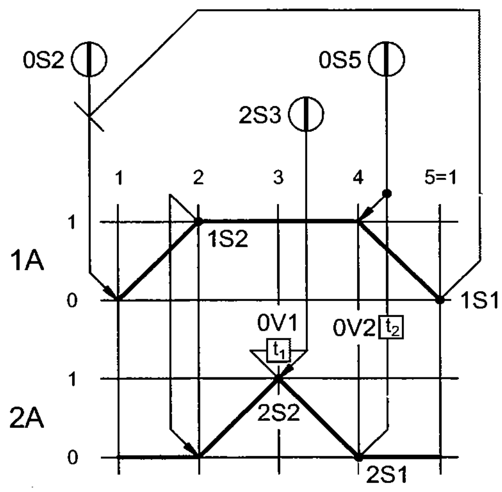


Fig. 6/3: Displacement-step diagram

Solution description

Initial position

The rodless cylinder (1A) is in its lefthand end position. The pneumatic proximity switch (1S1) emits a one-signal, flow 1-2. The double-acting cylinder (2A) is in its retracted end position. The roller lever valve (2S1) is actuated. The 5/2-way valve with selector switch (0S1) is switched to automatic, flow 1-2.

Step 1-2 –
The rodless linear drive (1A) extends to the right via the electroplating bath (movement 1A+).

The START signal is input into the first module of the sequencer, port Yn, via the 3/2-way valve (0S2) and via the dual-pressure valve (0V6) (module 4 is deactivated via line Z). The final control element (1V2) is reversed via line P1 and the cylinder (1A) moves to the right.

Step 2-3 –
Double-acting cylinder (2A) immerses the wire basket into the electro-plating bath (movement 2A+).

The magnet of cylinder (1A) switches the pneumatic proximity switch (1S2). Flow 1-2. The signal is transmitted to input X1 of the stepper module (0Z3). The sequencer switches to the second module. The final control element (2V2) is reversed via the line S2. The cylinder (2A) extends and actuates the roller lever valve (2S2) in its forward end position.

Step 3-4 –
Double-acting cylinder (2A) lifts the wire basket (movement 2A-).

When the set time t_1 = 5 sec has elapsed, the time delay valve (0V1) switches to flow. The signal pressurises input X2 of the second module in the sequencer. The third module is set. The final control element (2V2) is reversed via line P3 and the shuttle valve (2V1). Cylinder (2A) retracts and actuates the roller lever valve (2S1) in its retracted end position.

Step 4-5 –
Rodless linear drive (1A) travels to the left (movement 1A-).

After the set time t_2 = 4 sec, the time delay valve (0V2) exhausts the control line of the 3/2-way pneumatic valve (0V3). This changes to flow in the normal position. Port X3 in the sequencer chain 1 is pressurised via the shuttle valve (0V5) (signal switch-off of the time delay valve (0V2) was inverted). Signal X3 switches to the fourth module. Shuttle valve (1V1) and final control element (1V2) are reversed via line P4. Linear drive (1A) retracts and actuates the pneumatic proximity sensor (1S1). Its signal switches module 4 in the sequencer chain. Signal Yn+1 is present at the dual-pressure valve (0V6). Now a new cycle can be started by a start signal.

Marginal conditions

- **To conclude electro-plating before the end of the time set (movement 2A-).**
  The bath immersion time can be interrupted by actuation of the 3/2-way valve (0S4), (2S2) is actuated. The signal of the valve (0S4) switches the final control valve (2V2) via the shuttle valve (0V4), the AND gate of the second sequencer module, line P3 and the OR gate (2V1). The immersing cylinder (2A) travels into its retracted end position.

- **To conclude draining before end of the time set (movement 1A-).**
  To remove the wire basked before the end of the time set at valve (0V2), the 3/2-way valve (0S5) is actuated. The final control valve (1V2) is reversed via the shuttle valve (0V5), the AND gate of the third sequencer module, the line P4 and the OR gate (1V1). Cylinder (1A) moves to the left into its initial position

- **RESET.**
  The controller can be reverted from any intermediate position back into the initial position by shifting the 5/2-way valve (0S1) to MANUAL and actuating the 3/2-way valve (0S3). The signal from the valve (0S3) reverses the final control valves (1V2) and (2V2) via the shuttle valves (1V1) and (2V1). Cylinders (1A) and (2A) return to their initial position. The same signal also returns the stepper module to the initial position via port L. RESETTING of the processor requires that the final module is of the type TAB (monitoring module) .

Further development

- Alter the tubing of the sequencer in such a way that the following motion sequences are produced.

  Abbreviated notation:

1.	**1A+**	**1A–**	**2A+**	**2A–**
2.	**1A+**	**2A+**	**2A–**	**1A–**
3.	**1A–**	**1A+**	**2A–**	**2A+**

- Why won't the controller function if the extension stepper module is used instead of the stepper module?

- What effect does continuous operation of the 3/2-way valves via push buttons (0S4) and (0S5) have?

Feed unit

Notes on procedure

- The convertible 3/2-way valves are for use as components (3V2) and (2V3). These valves are supplied in the normally closed position. The valves are to be converted to the normally open position by interchanging the blanking plug and working port.
- Alternatively, a 5/2-way valve may also be used, in which case working port 4 must be plugged. In addition, a T-piece (quick push-pull distributor) and short piece of tubing are to be attached to the valve. The remaining two connections of the T-piece are to be connected together by means of a short piece of tubing.
- The correct stepper module is to be used. Why is it not possible to use the extension stepper module?
- Valve (0V5) is to be converted: Plug port 2 (T-piece).
- Checking of the complete assembly is facilitated, if the functions and positions of the valves have already been determined, identified and checked.
- If the control system no longer functions: check the sensor signals.
- Valves for marginal conditions (operating functions)

START	(0S6);
RESET	(0S4);
STOP at END OF CYCLE	(0S5);
MANUAL/AUTOMATIC	(0S3);
EMERGENCY-STOP	(0S1);
EMERGENCY-STOP unlatching	(0S2).

  Label your circuit diagram with these functions.
- The linear drive (3A) is equipped with two one-way flow control valves, which must be completely open as these will not be required.

- **Test run**

1. EMERGENCY-STOP (0S1) in normally closed position.
2. Actuate EMERGENCY-STOP unlatching (0S2), so that the memory (0V1) has flow from 1-2 (left switching position).
3. RESETTING the sequencer: Set valve with selector switch (0S3) to "MAN" and actuate push button (0S4).
4. START: Set valve (0S3) to "AUTO" and actuate push button (0S6) (START).
5. EMERGENCY-STOP: Actuate valve (0S1), i.e.
   - cylinder (1A) completes the movement which was started (though not the rest of the cycle),
   - actuator (2A) extends,
   - linear drive (3A) is exhausted on both sides.
6. Unlatching (0S2): The cycle is concluded as normal.

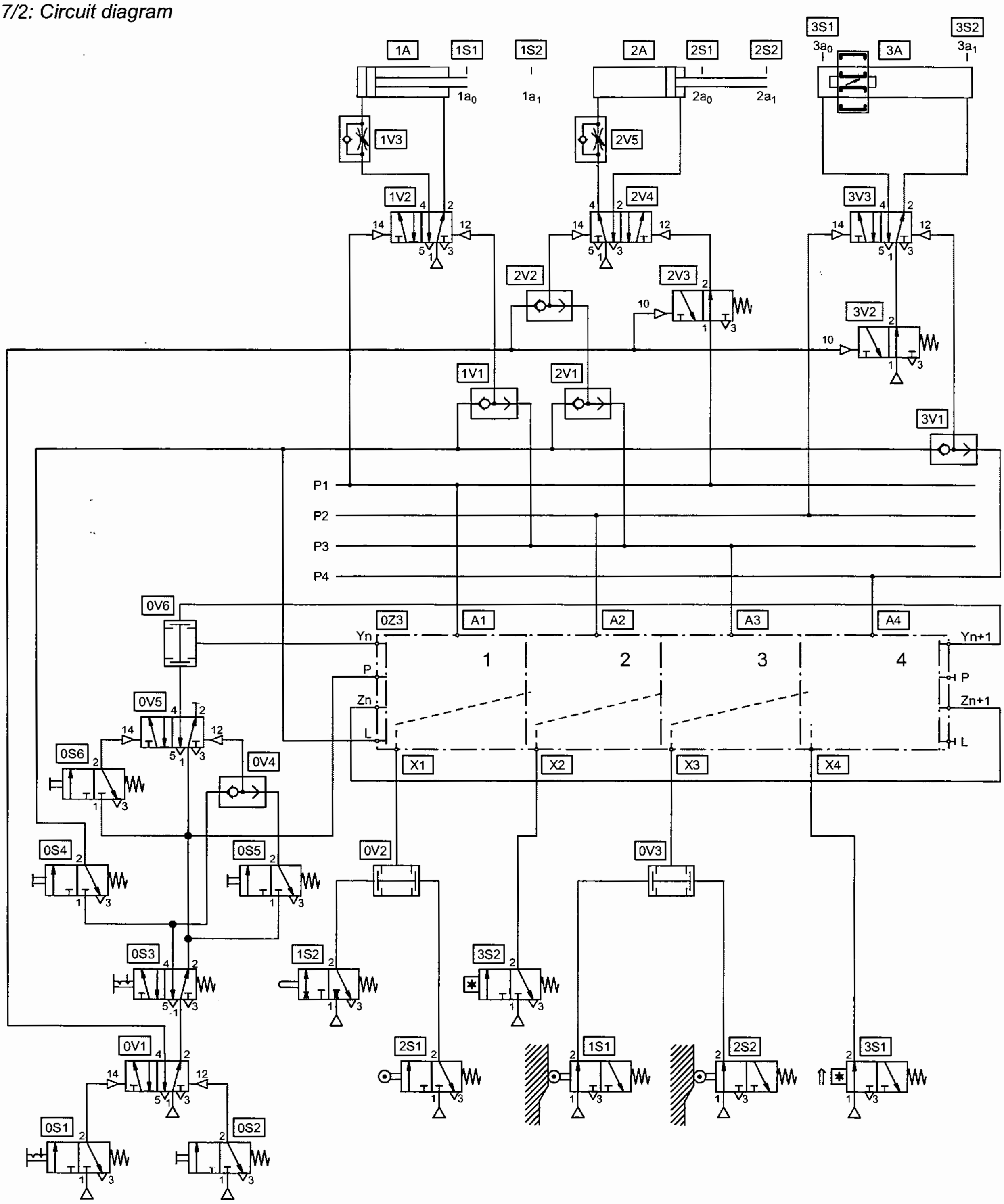
Components list

Components	Quantity	Designation
1A, 2A	2	Double-acting cylinder
3A	1	Linear drive, pneumatic
0V1, 0V5, 1V2, 2V4, 3V3	5	5/2-way double pilot valve
0V2, 0V3, 0V6	1	Dual-pressure valve, 3-fold
0V4, 1V1, 2V1, 2V2, 3V1	2	Shuttle valve, 3-fold
2V3, 3V2	2	3/2-way pneumatic valve, convertible
1V3, 2V5	2	One-way flow control valve
0S1	1	3/2-way valve with selector switch, normally closed
0S2, 0S4, 0S5, 0S6	4	3/2-way valve with push button, normally closed
0S3	1	5/2-way valve with selector switch
1S1, 2S1, 2S2	3	3/2-way roller lever valve, normally closed
1S2	1	Back pressure valve
3S1, 3S2	2	Pneumatic proximity switch
0Z3	1	Stepper module
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	20	Push-in T-connector

Components (0Z2) and (0Z1) are not shown in the circuit diagram.

Solution 7

Fig. 7/2: Circuit diagram



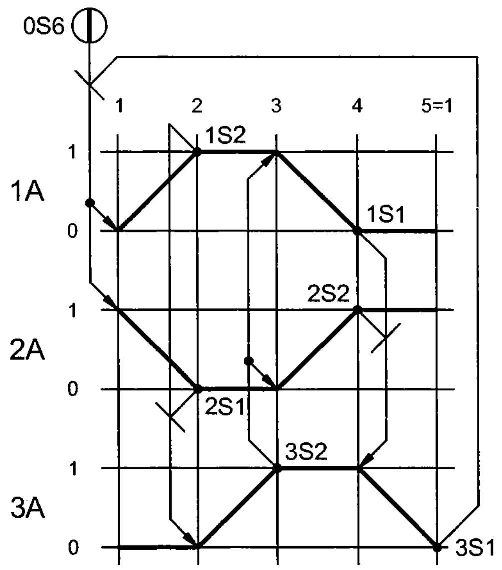


Fig. 7/3: Displacement-step diagram

Solution description

Initial position

The double-acting cylinder (1A) is located in its retracted end position. It actuates the roller lever valve (1S1). The double-acting cylinder (2A) has extended and actuates the roller lever valve (2S2). The pneumatic linear drive (3A) is in its lefthand end position and actuates the pneumatic proximity switch (3S1). The 5/2-way valve (0S3) is latched to flow from 1-2. The 3/2-way valve (0S1) "EMERGENCY-STOP" is unlatched. The memory valve (0V1) has flow from 1 to 2. The sequencer chain is set.

Continuous cycle

Step 1-2 –
Cylinder (1A), feed gripper, extends and clamps the plastic strip. Cylinder (2A), holding gripper, retracts and releases the plastic strip.

The START signal (0S6) switches the memory valve (0V5) to flow from 1 to 4. Now air flows through valves (0S3), (0S6), (0V5) and a continuous signal is present at the dual-pressure valve (0V6). The dual-pressure valve (0V6) can input the start signal to the sequencer chain together with the signal Yn+1 of the last stepper module in the chain. The output signal A1 reverses final control elements (1V2) and (2V4) simultaneously via line P1 so that cylinder (1A) extends and cylinder (2A) retracts with air throttled.

Step 2-3
Feed cylinder (3A) travels to the right, i.e. the plastic strip is moved to the right by one stroke length, whilst cylinder (1A) clamps the strip.

As soon as cylinder (1A) has reached its forward end position and cylinder (2A) reaches its retracted end position, the sequencer is advanced by acknowledgement signal X1. The dual-pressure valve (0V2) ensures that a signal only arrives at X1 when both the back pressure valve (1S2) and the roller lever valve (2S1) are actuated. Signal A2 reverses the final control valve (3V3) via line P2. The pneumatic linear drive travels to the right and actuates the pneumatic proximity switch (3S2) in its end position.

Step 3-4 –
Cylinder (1A) retracts, the plastic strip is released by the feeding gripper. Cylinder (2A) extends, and the plastic strip is held by the holding gripper.

The acknowledgement signal of the proximity switch (3S2) advances the sequencer by one step via port X2. The positioning command A3 reverses the final control elements (1V2) and (2V4) via the control line P3. Cylinder (1A) travels into its retracted end position and actuates the roller lever valve (1S1), cylinder (2A) travels into its forward end position and actuates the roller lever valve (2S2).

Step 4-5
Feed cylinder (3A) travels to the left (idle stroke), whilst the holding gripper retains the strip.

If the end positions of cylinders (1A) and (2A) have been acknowledged (initial position), the signal X3 of the dual-pressure valve (0V3) advances the sequencer by one step. The positioning command A4 reverses the final control element (3V3) via line P4. The pneumatic linear drive travels to the left. A cycle is concluded.
Two signals are once again present at the dual-pressure valve (0V6), the continuous signal from the memory valve (0V5) and signal Yn+1 from the sequencer. Thus, all further cycles proceed without a renewed START signal - continuous cycle.

Marginal conditions

- **STOP at END OF CYCLE**
  The memory valve (0V5), obtained in this exercise by converting a 5/2-way pneumatic pilot valve, can be reversed by the 3/2-way valve (0S5). The line to the AND valve (0V6) is exhausted. The start signal Yn+1 for the next cycle is then blocked by the AND valve (0V6).

- **EMERGENCY-STOP**
  When the EMERGENCY-STOP valve (0S1) is actuated, the memory valve (0V1) is reversed, flow 1-4. The start processors are exhausted. The final control element (2V4) is reversed via port 14. The cylinder with holding gripper extends. Port 12 of the final control element (2V4) is exhausted by the 3/2-way pneumatic valve (2V3), thus ensuring that the final control element is actually able to switch to flow from 1-4. The pressure line to the final control element (3V3) is exhausted via the 3/2-way pneumatic pilot valve (3V2). In this way, the pneumatic linear drive is brought to a stop.

- **EMERGENCY-STOP unlatching and RESET**
  After EMERGENCY-STOP, the actuating section must first of all be returned to its initial position before EMERGENCY-STOP unlatching is actuated, as otherwise the plastic strip might be damaged (feed movement EMERGENCY-STOP, cylinder (1A) and (2A) hold the strip in place. EMERGENCY-STOP unlatching: the actuating section starts up once again from the old position, at the same time the strip can be folded). Thus, it is necessary to observe the following switching procedure: EMERGENCY-STOP, switch over from “AUTOMATIC” to “MANUAL”, and only then actuate EMERGENCY-STOP unlatching. Compressed air is now available for “RESET”.

Packing of spark plugs

Notes on procedure

- The convertible 3/2-way pneumatic valves are to be used as components (0V5) and (0V8). These valves are supplied in the normally closed position. The valves are to be converted to normally open position by interchanging the blanking plug and working port.
  Alternatively, a 5/2-way pneumatic valve may also be used, in which working port 4 must be plugged. In addition a T-piece (quick push-pull distributor) and a short piece of tubing are to be attached to the valve. The remaining two connections of the T-piece are to be connected together by means of a short piece of tubing.
- As a third 3/2-way pneumatic valve is not available, a 5/2-way pneumatic valve must be used for valve (0V2). Output 2 is to be plugged.
- In practice, a roller lever valve (0S5) is used to check whether the gravity feed magazine has been filled. However, this is not relevant in this case, as continuous actuation of the valve is not planned. A 3/2-way valve with selector switch is suggested for simulation purposes.
- The circuit diagram shows the sequencer (0Z3) to have three modules. The Festo Didactic stepper module is equipped with four modules. To overcome this, bridge the second stage by connecting together output A2 and input X2.
- When bridging stages, the following applies:
  - the last positional status should not be an idle step
  - do not switch two idle steps one directly after the other.
- Observe the following:
  Proximity sensors, in particular, should be checked to ensure they are functioning properly. Identify all switches and their positions.
- The valves for the marginal conditions are:
  STOP AT END OF CYCLE (0S4),
  START (0S3),
  RESET (0S2),
  AUTOMATIC/MANUAL (0S1).
- **Test run**
  Proceed as follows
  1. Reset: “MAN” and “RESET”
  2. Start: “AUTO” and “START”
  3. Interrupt: “STOP at END OF CYCLE”

Components list

Components	*Quantity*	*Designation*
1A, 2A	2	Double-acting cylinder
0V1, 1V1, 2V1	1	Shuttle valve, 3-fold
0V2	1	5/2-way pneumatic valve
0V4, 0V6, 0V7, 0V9	2	Dual-pressure valve, 3-fold
0V5, 0V8	2	3/2-way pneumatic valve, convertible
1V2, 2V2	2	5/2-way double pilot valve
1V3, 1V4, 2V3, 2V4	4	One-way flow control valve
0S1	1	5/2-way valve with selector switch
0S2, 0S3, 0S4	3	3/2-way valve with push button, normally closed
0S5, 1S1, 1S2	3	3/2-way roller lever valve, normally closed
2S1, 2S2	2	Pneumatic proximity switch
0V3	1	Pneumatic preselect counter
0Z3	1	Stepper module
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	22	Push-in T-connector

Components (0Z2) and (0Z1) are not shown in the circuit diagram.

Fig. 8/2 Circuit diagram

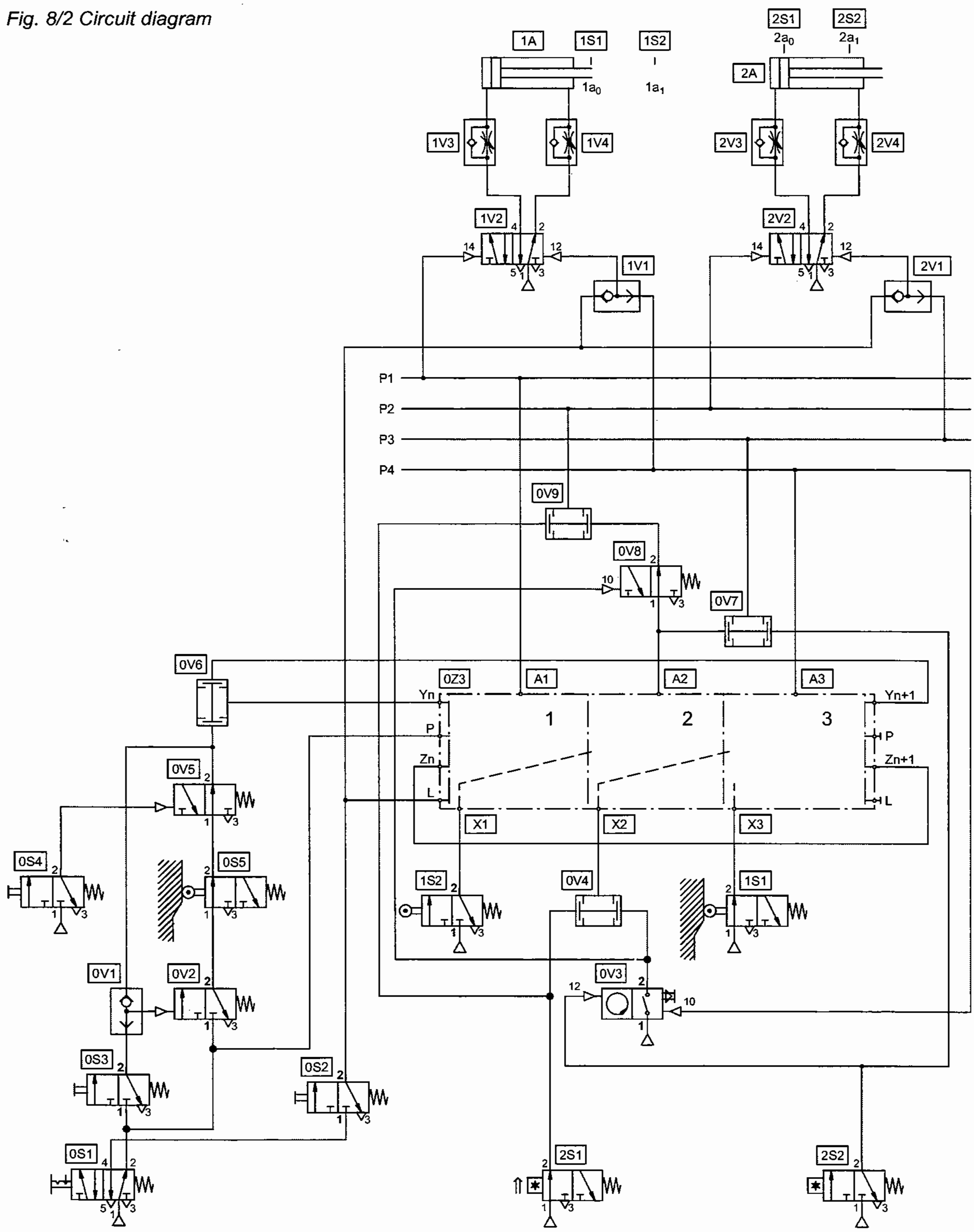
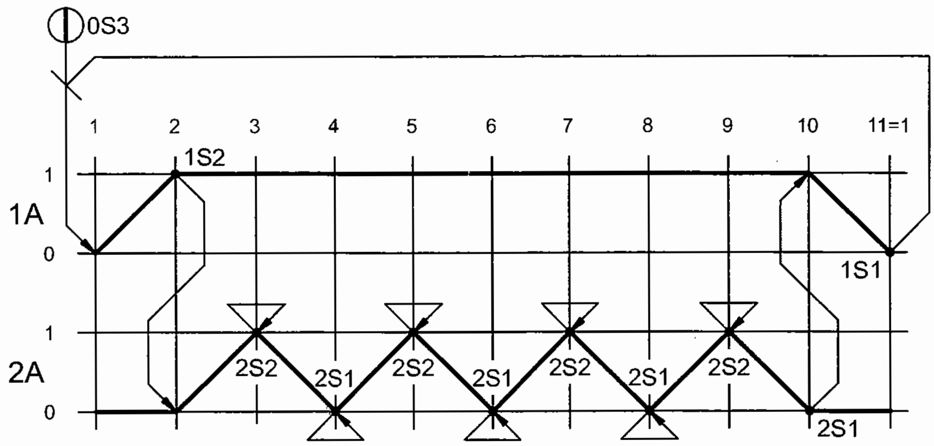


Fig. 8/3: Displacement-step diagram



Solution description

Initial position

The double-acting gravity feed cylinder (1A) is located in its retracted end position and actuates the roller lever valve (1S1). The double-acting horizontal magazine cylinder (2A) is also located in its retracted end position and actuates the pneumatic proximity switch (2S1). The 5/2-way valve (0S1) is latched so that flow is from 1-2. The roller lever valve (0S5) or a 3/2-way valve with selector switch is actuated (full carton magazine is simulated).

Continuous cycle

Step 1-2 – Gravity feed cylinder (1A) extends.

The pneumatic valve (0V2) is switched to flow from 1-2 by means of the START signal of the 3/2-way valve (0S3) via the shuttle valve (0V1). The valve self-latches via valve (0S5), valve (0V5) (flow in the normal position) and the shuttle valve (0V1). This self-latching produces a continuous signal at the AND gate (0V6). The actuating section is set in operation together with the signal Yn+1 of the last module of the sequencer. The output signal A1 of the sequencer switches the final control element (1V2) to flow from 1-4 via line P1. Cylinder (1A) travels throttled and actuates the roller lever valve (1S2) in its forward end position.

**Step 2-3 to 9-10 –
Horizontal magazine cylinder (2A) executes four double strokes.**

The sequencer is advanced by acknowledgement signal X1. Output signal A2 of the sequencer is applied together with the signal from the actuated proximity switch (2S1) applied at the dual-pressure valve (0V9) and switches the final control element (2V2) to flow 1-4 via line P2. Cylinder (2A) extends throttled and actuates the proximity switch (2S2) in its forward end position. The resulting signal is applied together with signal A2 of the sequencer to the AND gate (0V7) and reverses the final control element (2V2) via line P3. Cylinder (1A) retracts again. Proximity switch (2S2) also emits a pulse to the pneumatic preselect counter (0V3). After the four strokes which have been set, the output signal of the counter is applied to the AND gate (0V4). Together with the signal from the proximity switch (2S1), the four strokes are acknowledged at X2, and the sequencer advances. The pneumatic valve (0V8) is exhausted via the same output signal from the counter. Only one signal is now present at the AND gate (0V9). Thus, the cylinder (2A) is no longer able to extend.

Step 10-11 – The gravity feed magazine cylinder (1A) retracts.

The output signal A3 reverses the final control element (1V2) via control line P4. Cylinder (1A) retracts and actuates the roller lever valve (1S1). The third module is enabled and the signal Yn+1 introduces a new cycle.

Marginal conditions

- **STOP AT END OF CYCLE**
  The pneumatic valve (0V5) exhausts the self-latching circuit by the actuation of the 3/2-way valve (0S4). The pneumatic valve (0V2) assumes the normally closed position. Thus, there is no signal at the AND gate (0V6). The sequencer can be reactivated by a renewed start signal.
- **RESET**
  If the 5/2-way valve with selector switch (0S1) is latched to MANUAL, the actuators and the sequencer can be brought into their initial position by actuating the 3/2-way valve (0S2).

Sealing device

Notes on procedure

- Use the 5/2-way pneumatic valves for items (1V3), (1V4) and (1V5) and plug outputs 4, as the valves need to be in the normally open position.
- The convertible 3/2-way pneumatic valves are to be used for items (0V3) and (0V2). Valve (0V3) is in the normally open position. Valve (0V2) is in the normally closed position.
- Activation of stepper module (0Z3):
  Please note the principle of the sequencer
  – Switching, i.e. passing on the signal from input X to output A
  – Setting the next step
  – Resetting the preceding step
    See also notes on procedure for exercise 5.

  Here, we have a case where the signal element activates two stepper modules simultaneously. Roller lever valve (1S1) provides inputs X2 and X4 at the same time. If the second step has been set, then it passes on the signal. If the fourth step is set, then the signal passes to line P4. Both step outputs are connected via the shuttle valve (1V2), i.e. both the second as well as the fourth step pass the pulse to the final control element (1V8) via lines P2 or P4 and via valves (1V4), (1V6) and (1V7).
- Attaching the sensors $1a_0$, $1a_m$ and $1a_1$:
  Proximity switch "$1a_m$" is shown on the lefthand side of the circuit diagram but is, however attached to the centre of the cylinder barrel. The connections of the proximity switch must point away from the piston rod, thus obtaining a high switching accuracy.

Test run

1. RESET: EMERGENCY-STOP to flow and RESET to flow
2. START: EMERGENCY-STOP to block, START to flow
3. EMERGENCY-STOP: ...
   - within a stroke: the cylinder assumes the retracted end position.
   - within an end position: the cylinder remains in the appropriate end position.
   - during the first stroke: a new START introduces a completely new cycle.
   - after the first stroke: the cycle which has started is completed with a new START command.

Components list

Components	*Quantity*	*Designation*
1A	1	Double-acting cylinder
0V2, 0V3	2	3/2-way pneumatic valve, convertible
1V3, 1V4, 1V5	3	5/2-way pneumatic valve
0V1, 1V1, 1V2, 1V6, 1V7	2	Shuttle valve, 3-fold
0V4	1	Dual-pressure valve
1V8	1	5/2-way double pilot valve
1V9, 1V10	2	One-way flow control valve
0S2	1	3/2-way valve with mushroom actuator, red, norm. closed
0S1, 1S4	2	3/2-way valve with push button, normally closed
1S1, 1S2	2	3/2-way roller lever valve, normally closed
1S3	1	Pneumatic proximity switch
0Z3	1	Stepper module
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	13	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 9/2: Circuit diagram

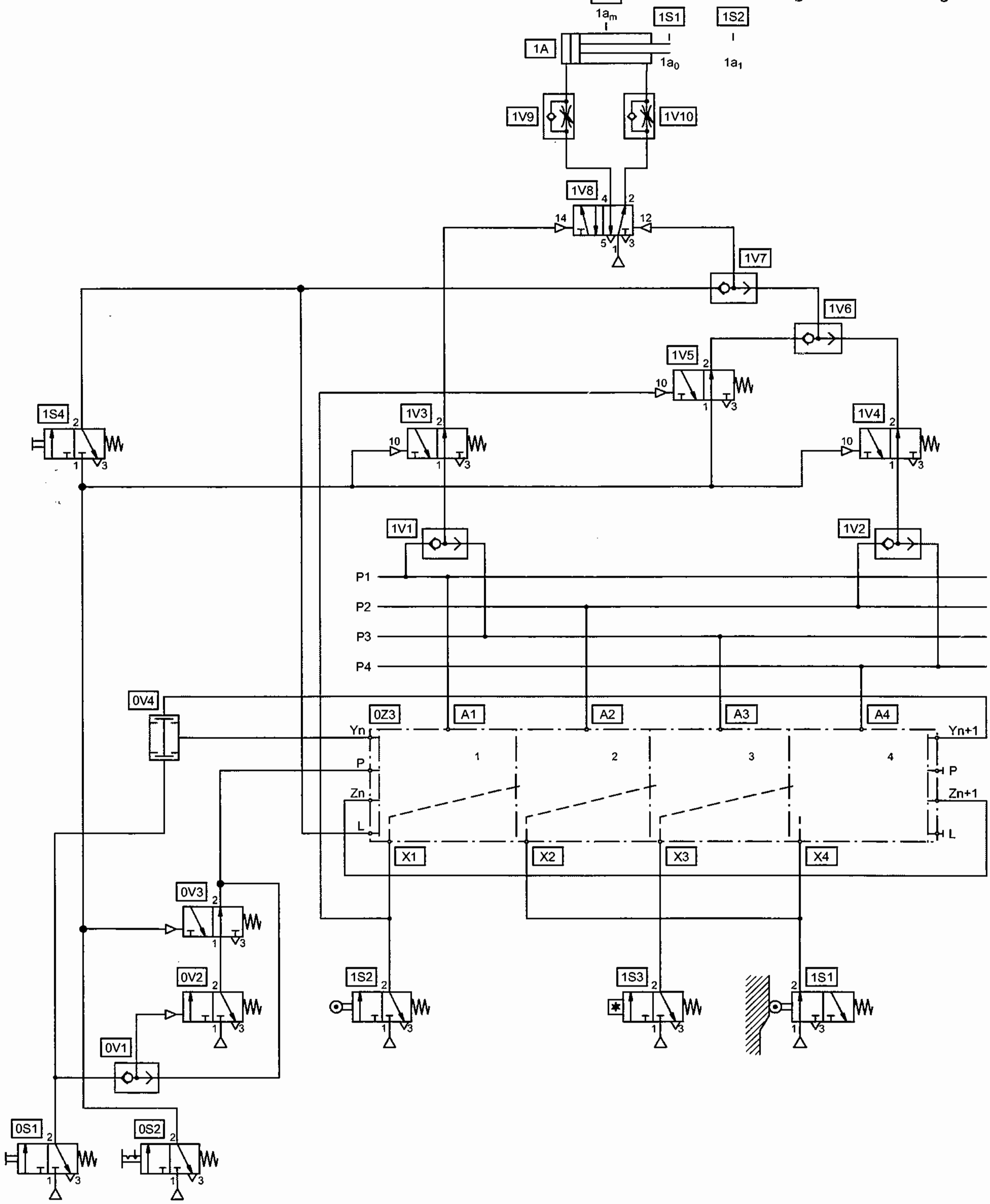
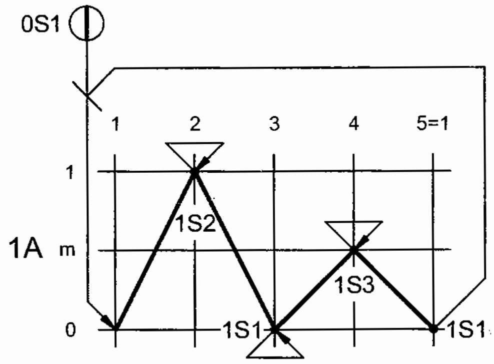


Fig. 9/3: Displacement-step diagram



Solution description

Initial position

The piston rod of the double-acting cylinder (1A) is located in its retracted end position and actuates the roller lever valve (1S1). The 3/2-way pneumatic valves (0V3), (1V3), (1V4), (1V5) assume the normally open position. The 3/2-way pneumatic valve (0V2), which is required for the self-holding circuit, assumes the normally closed position.

Step 1-2 – The piston rod travels into its forward end position.

The START signal of the 3/2-way valve (0S1) causes the pneumatic valve (0V2) to be switched to flow via the shuttle valve (0V1). The control air is now able to flow via valve (0V3) to the sequencer, port P. At the same time, this control air passes a continuous signal to the 3/2-way pneumatic valve (0V2) via the shuttle valve (0V1). This valve now creates a self-holding circuit. The compressed air supply for the sequencer is protected. As a result of the start signal and signal Yn+1, pressure is applied to both sides of the dual-pressure valve (0V4), which switches through. The sequencer can now activate the final control element. Output signal A1 from the sequencer switches the final control element (1V8) via line P1, shuttle valve (1V81) and pneumatic valve (1V3). The piston rod extends and actuates the roller lever valve (1S2) in the forward end position. Travelling past the proximity switch (1S3) has no effect.

Step 2-3 – The piston rod travels into the retracted end position.

The signal from the roller lever valve (1S2) advances the sequencer. The output signal from the sequencer A2 reverses shuttle valve (1V2), pneumatic valve (1V4), shuttle valves (1V6) and (1V7) and the final control element (1V8) via line P2. The piston rod retracts and actuates the roller lever valve (1S1). The signal line from valve (1S2) to valve (1V5) is only of significance in case of EMERGENCY-STOP.

Step 3-4 – Piston rod extends half-way.

The sequencer is advanced by the acknowledgement signal X2 of roller lever valve (1S1). (The AND gate of the fourth module is not yet set, hence the signal to X4 is not able to advance the sequencer). Travelling past the proximity switch (1S3) alsom had no effect, since the third module was not yet set.) Output signal A3 reverses the final control element (1V8) via control line P3, shuttle valve (1V1) and pneumatic valve (1V3). The piston rod extends and actuates the proximity switch (1S3).

Step 4-5 – Piston rod extends into the forward end position.

Now the acknowledgement signal from the proximity switch (1S3) is able to advance the sequencer via port X3. The output A4 reverses the final control element (1V8) via line P4, shuttle valve (1V2), pneumatic valve (1V4) and shuttle valves (1V6) and (1V7). The piston rod retracts. Valve (1S1) acknowledges the end position of the piston rod at port X4. Signal Yn+1 is once more applied to the dual-pressure valve (0V4). The next cycle can now be started with a renewed start signal.

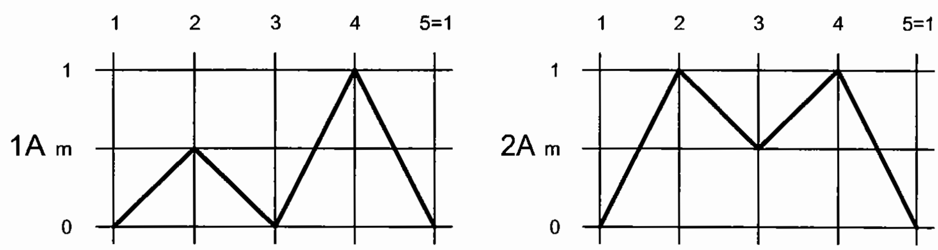
Marginal conditions

- **EMERGENCY-STOP**
  whilst piston rod is in **"forward movement"**.
  If the EMERGENCY-STOP mushroom actuator (0S2) is actuated, the self-latching circuit of the compressed air supply for the sequencer is first of all interrupted by valve (0V3). This means that the sequencer is not able to emit any output signals. The EMERGENCY-STOP signal blocks valves (1V3) and (1V4) and reverses the final control element (1V8) via valves (1V5), (1V6) and (1V7). The piston rod travels into its retracted end position.
- **EMERGENCY-STOP**
  piston rod is in **"retract movement"**.
  The final control element (1V8) already has flow from 1-2. The piston rod thus travels into its retracted end position.
- **EMERGENCY-STOP**
  piston rod is in its **forward end position**.
  The final control element is switched to flow from 1-4. The roller lever valve (1S2) is actuated and blocks the valve (1V5). Thus, the line for the EMERGENCY-STOP signal to the final control element is interrupted. The piston rod remains in its forward end position.
- **RESET**
  The EMERGENCY-STOP mushroom actuator remains pressed down, the sequencer is returned to its initial position by the valve (1S4) and the final control element (1V8) is reversed by the shuttle valve (1V7). The piston rod travels into its retracted end position.

Further development

- Replace the two roller lever valves in the end positions with proximity switches.
- Exchange the double-acting cylinder for the pneumatic linear drive.
- Implement the following two motion sequences independently of the previous problem definition.

Fig. 9/4



Hardening of material samples

Notes on procedure

Components

Valve (1V2) is an additional time-delay valve from the TP102 equipment set. It is a normally open valve and therefore has to be inverted for this circuit diagram. This task is carried out by the 3/2-way valve (1V3). For the purpose of the practical assembly, this is achieved by means of a 5/2-way pneumatic valve. The time delay valve (1V2) is actuated in the initial position as the last step of the sequencer is set.

Arrangement and setting

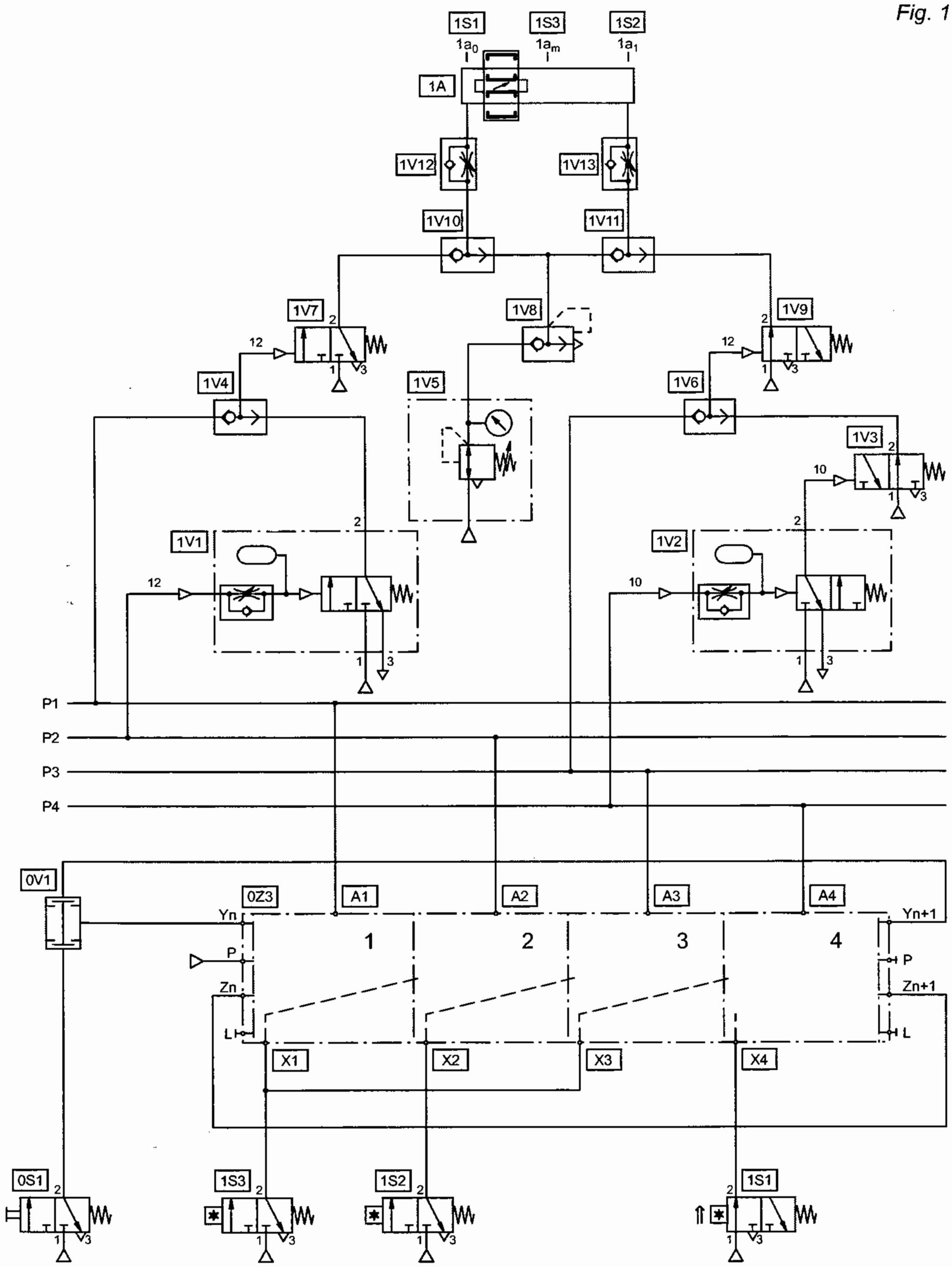
- Arrange the components on the profile plate to resemble the circuit diagram as closely as possible. Identify the components and their functions using a soft pencil or self-adhesive labels.
- The connection of the sensors (1S1), (1S2) and (1S3) is already familiar from the previous exercises.
- Use one of the two shuttle valves, 3-fold, for the OR-function (1V4) and (1V10). Use the second shuttle valve, 3-fold, for the OR-function (1V6) and (1V11).
- Adjustment of the proximity switches always causes problems.
- Setting problems occur in respect of the stopping times t_1 and t_2 of the linear drive in the mid-position (1V1) for advance stroke (1V2) for return stroke. Use a stop watch for this.
- In the same way, a certain degree of patience is required to achieve the identical mid-position when approaching from the left or right since the prepressurised air cushioning at p = 4 bar (400 kPa) can have varying effects on the piston (setting the one-way flow control valves).
  Prepressurisation (1V5) and (1V8) is required to avoid a jerky approach to the stopping position. If prepressurisation is used, the linear drive approaches it evenly. Matching of pressures is essential. If the prepressurisation is too high, then there will be no jump, but instead the "stick-slip" effect will occur.
- In the mid-position, the feed unit is not controlled for a brief period, i.e. it is able to move against a pressure of p = 4 bar (400 kPa), since the time delay valves do not pass on any signals during this stationary phase, i.e. (1V7) and (1V9) are not actuated and, as a result, an identical pressure is produced at the piston via (1V5) and (1V8)
- For the practical circuit construction, the two one-way flow control valves (1V12) and (1V13) will not be required since the linear drive (1A) is already equipped with two one-way flow control valves.

Components list

Components	*Quantity*	*Designation*
1A	1	Linear drive, pneumatic
0V1	1	Dual-pressure valve
1V3	1	5/2-way pneumatic valve
1V4, 1V6	2	Shuttle valve, 3-fold
1V8	1	Quick exhaust valve
1V7, 1V9	2	3/2-way pneumatic valve, convertible
1V12, 1V13	2	One-way flow control valve
0S1	1	3/2-way valve with push button, normally closed
1S1, 1S2, 1S3	3	Pneumatic proximity switch
1V5	1	Pressure regulator with pressure gauge
1V1	1	Time delay valve, normally closed
1V2	1	Time delay valve, normally open
0Z3	1	Stepper module
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	18	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 10/2: Circuit diagram



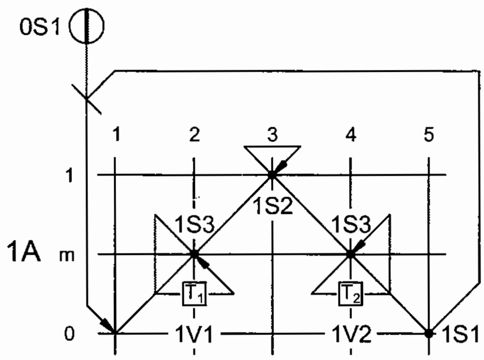


Fig. 10/3: Displacement-step diagram

Solution description

Initial position

The pneumatic linear drive (1A) is located in the lefthand end position. It actuates the pneumatic proximity switch (1S1); as a result, the continuous signal Yn+1 is applied to the dual-pressure valve (0V1). The fourth module (type B) of the sequencer is set. Its signal A4 blocks the time delay valve (1V2). The pneumatic valve (1V3) is not actuated and is normally open. As a result, the control port of the final control element (1V9) is pressurised. The righthand cylinder chamber of the actuator is supplied with a pressure of p = 6 bar (600 kPa). The lefthand cylinder chamber of the actuator is supplied with a pressure of p = 4 bar (400 kPa) via the pressure regulator (1V5), the quick exhaust valve (1V8), the shuttle valve (1V10) and the one-way flow control valve (1V12).

Step 1-2 –

The linear drive moves to the mid-point annealing position.

The first module (type A) of the sequencer is set by the START signal of the 3/2-way push-button valve (0S1). Its signal A1 actuates the final control element (1V7), a spring-returned 3/2-way pneumatic valve. The higher pressure of the working air seals the righthand port of the shuttle valve (1V10). The working air flow flows into the lefthand cylinder chamber. The piston begins to move. The exhaust air is under a pressure of p = 4 bar (400 kPa). It is released to atmosphere via quick exhaust valve (1V8). The actuator operates the proximity switch (1S3) in mid-position.

Step 2-3 –
Pause until annealing time is over; then linear drive travels to the righthand end position for plunging.

The acknowledgement signal for the proximity switch (1S3) is applied to connections X1 and X3 of the sequencer, but can only be switched via the first module set. Its signal A2 actuates the time delay valve (1V1). During the set annealing time of t_1 = 5 seconds, the actuator is pressurised from both sides. Valves (1V7) and (1V9) are exhausted. After 5 seconds, the final control element (1V7) is reversed via (1V1) and (1V4). The actuator travels into its righthand end position and actuates the proximity switch (1S2).

Step 3-4 – Linear drive travels into mid-position for tempering.

The acknowledgement signal for the proximity switch (1S2) switches to the third stepper module. Its signal A3 switches the final control element (1V9) to flow. The actuator travels to the left into the mid-position and actuates the proximity switch (1S3) once again.

Step 4-5 –
Pause for tempering to expire; linear drive travels into the end position.

The acknowledgement signal from the proximity switch (1S3) switches through to the fourth module (type B) of the sequencer via connection X3. The signal X1 has no effect since module 1 has not been set. Signal A4 (a continuous signal) actuates the time delay valve (1V2). After the tempering time of t_2 = 2 seconds the final control element (1V9) is switched to flow via (1V3) and (1V6). The linear drive travels into the initial position. A new cycle can be started via another manual START signal.

Further development

- Arrange the linear drive (1A) vertically (or at an angle). The weight of the slide will now affect movement. What problems are likely to result?
- What motion sequence is produced when the value t_1 = 0 seconds is set for time delay valve (1V1), and the value t_2 = 0 seconds for time delay valve (1V2)?
- What is the consequence of exchanging the stepper outputs A3 and A4?
- Why is it not possible to change linear drive (1A) for a double-acting cylinder without changing the circuit? Modify the control system accordingly.
- Replace the two 3/2-way pneumatic valves (1V7) and (1V9) respective with a 5/3-way pneumatic valve (see list of additional components). This valve which has three switching positions is spring centred and pressurised on both sides.

Bending device

Notes on procedure

Recommended valves

1. The final control element (1V2) is a convertible 3/2-way pneumatic valve.
2. The "memories" (0V2) and (0V3) are obtained through the 5/2-way double pilot valves. Output 4 is to be plugged into valve (0V3), and output 2 on valve (0V2).

Attachment of sensors

Roller lever valves (1S1), (2S1) and (2S2) are to be mounted in the usual way and checked for correct switching.

The attachment and checking of proximity switches is carried out as in the previous exercises. Sensor (1S2), the back pressure valve, must be readjusted accurately (release the lock nut and twist the screw-in nozzle), as the single-acting cylinder (1A) may have a different stroke length than the double-acting cylinder.

Response to setpoint changes

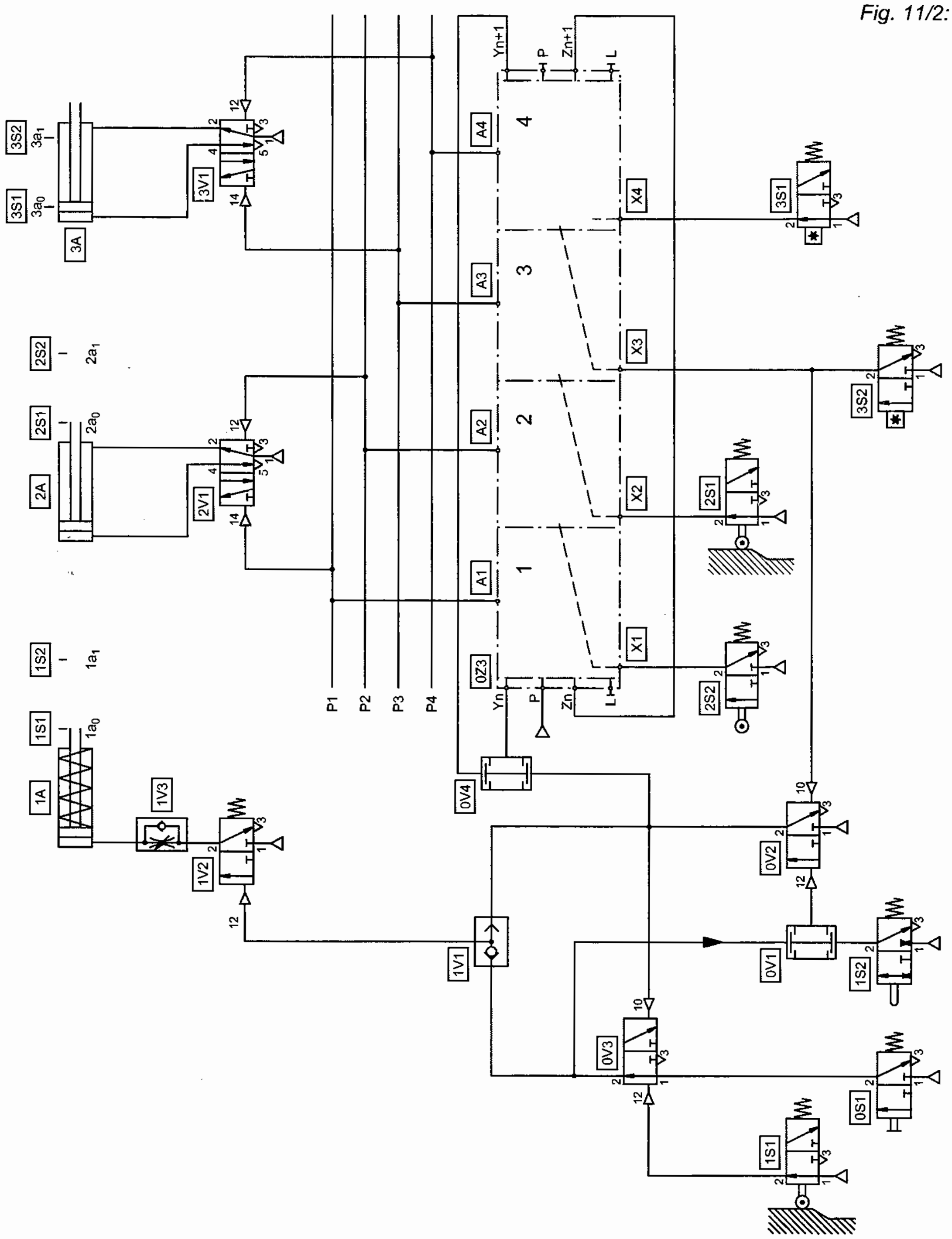
Before the bending operation starts, reliable clamping must take place. The back pressure valve (1S2) ensures reliable operation of the clamping cylinder. The manually operated valve (0S1) must remain actuated until the back pressure valve (1S2) reacts. This latching ensures the bending operations which follow.

Components list

Components	*Quantity*	*Designation*
1A	1	Single-acting cylinder
2A, 3A	2	Double-acting cylinder
0V1, 0V4	2	Dual-pressure valve, 3-fold
0V2, 0V3, 2V1, 3V1	4	5/2-way double pilot valve
1V1	1	Shuttle valve
1V2	1	3/2-way pneumatic valve, convertible
1V3	1	One-way flow control valve
0S1	1	3/2-way valve with push button, normally closed
1S2	1	Back pressure valve
1S1, 2S1, 2S2	3	3/2-way roller lever valve, normally closed
3S1, 3S2	2	Pneumatic proximity switch
0Z1	1	On-off valve with filter regulator
0Z2	1	Manifold
0Z3	1	Stepper module
	19	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 11/2: Circuit diagram



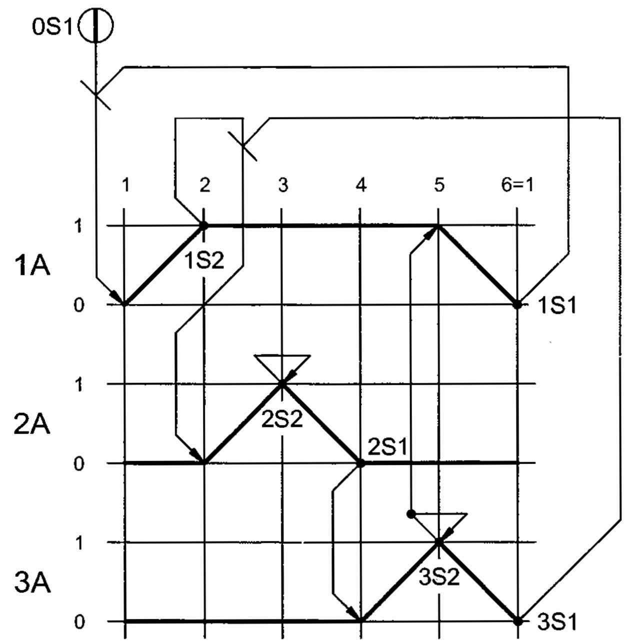


Fig. 11/3: Displacement-step diagram

Solution description

Initial position

The three actuators are located in their retracted end positions. Sensors (1S1), (2S1) and (3S1) are actuated. Memory valve (0V3) is switched to flow from 1-2. Memory valve (0V2) is closed.

Step 1-2 – The clamping cylinder (1A) extends (1A+).

If the START valve (0S1) is actuated, the final control element (1V2) switches to through flow. The single-acting cylinder (1A) extends with air supply throttled and actuates the back pressure valve (1S2) in its forward end position. Two signals are now applied to the dual-pressure valve (0V1), (1st the start signal and then the acknowledgement signal for the movement 1A+). The final control element (1V2) remains actuated via the memory valve (0V2) and the shuttle valve (1V1). The clamping cylinder remains in its forward end position.

Step 2-3 – The first bending cylinder (2A) extends (2A+).

A signal is also applied to the dual-pressure valve (0V4) via the memory valve (0V2). The first module (type A) of the sequencer is set together with signal Yn+1. Its signal A1 reverses the final control element (2V1). Cylinder (2A) extends and actuates the roller lever valve (2S2).

Step 3-4 – The first bending cylinder (2A) retracts (2A-).

The second module (type A) is set via the acknowledgement signal of the roller lever valve (2S2). Its signal A2 reverses the final control element (2V1); the cylinder (2A) travels into its retracted end position and actuates the roller lever valve (2S1).

Step 4-5 – The second bending cylinder (3A) extends (3A+).

The third module (type A) is set via the acknowledgement signal of the roller lever valve (2S1). Its signal A3 reverses the final control element (3V1). The cylinder (3A) extends into its forward end position and actuates the pneumatic proximity switch (3S2).

Step 5-6 –
The second bending cylinder (3A) and the clamping cylinder (1A) retract (3A-), (1A-).

First of all, the acknowledgement signal of valve (3S2) switches to the fourth module (type B). Its signal A4 reverses the final control element (3V1). Cylinder (3A) retracts and actuates the proximity switch (3S1). Secondly, the memory valve (0V2) is exhausted. As a result, there is no longer a continuous signal at the final control valve (1V2). Cylinder (1A) also retracts and actuates the roller lever valve (1S1). Now, the initial position is reached once again. The fourth module of the sequencer is switched. Its signal Yn+1 is applied to the dual-pressure valve (0V4). The memory valve (0V3) is once again in the righthand switching position. A new cycle can be started via a START-signal from the valve (0S1).

Further development

The sequencer in the constructed control system starts when the back pressure valve (1S2) has been actuated by the switching cam of the clamping cylinder (1A).

Complete the control system in such a way that the sequencer does not start until the clamping cylinder (1A) has reached its forward end position and a pressure of p = 4 bar (400 kPa) has built up in the piston chamber.

Cleaning pant for housing parts

Notes on procedure

Arrangement

The cylinders required here and their activation present a problem of space since if they were arranged horizontally, the piston rods would interfere with the cylinders assembled next to them. A vertical arrangement - piston rods extending beyond the profile plate - is to be recommended.

Components

- The cylinder (3A) must be replaced by the linear drive.
- Two stepper modules are used for the first time. Arrange these correctly! Left: Stepper module, extension, Right: stepper module. Connection takes place out as follows: The L-ports (insofar as RESET is intended) and the P-ports of the two modules are connected via T-pieces and fed towards the pressure sources. Connection Zn+1 of the first step is connected to Zn of the second step. Zn+1 of the second step is connected to Zn of the first step. The same applies to the Y-ports, whereby Yn+1 of the second step is to be connected to Yn of the first step and the START button via a dual-pressure valve (AND).
- Ensure that the pressure gauge (0Z3) is installed in the line system. The T-piece is located on the component.
- The one-way flow control valve (3V3) is not required for the practical circuit construction since the linear drive (3A) is equipped with two one-way flow control valves. See also circuit design.

Function check

- Check the final control valve (2V1). The 3/2-way double pilot valve is obtained through a 5/2-way double pilot valve. Output 2 is closed.
- The total sequence is executed very quickly. To be able to follow the motion sequence visually and mentally, the movements can be slowed down by reducing the pressure. For this, the pressure sequence valve (0V1) has to be reset. It does not function accurately below a pressure of p = 1.8 bar (180 kPa). The use of very long tubing also causes a delay and the build up in pressure at the pressure gauge can thus be clearly observed.

- The roller lever valves can be put to one side and operated manually so that the stroke sequence takes place step by step by means of manual operation. The sequence of signals from the proximity switches can be slowed down by throttling the cylinders (3A) and (4A).

Components list

Components	*Quantity*	*Designation*
1A, 4A	2	Double-acting cylinder
2A	1	Single-acting cylinder
3A	1	Linear drive, pneumatic
0V2, 0V3	2	Dual-pressure valve
1V1, 2V1, 3V1, 4V1	4	5/2-way double pilot valve
1V2, 4V2	2	One-way flow control valve
3V2	1	Quick exhaust valve
0S1	1	3/2-way valve with push button, normally closed
1S1, 1S2, 2S1	3	3/2-way roller lever valve, normally closed
3S1, 3S2, 4S1	3	Pneumatic proximity switch
4S2	1	Back pressure valve
0V1	1	Pressure sequence valve
0Z4	1 1	Stepper module Stepper module, extension
0Z3	1	Pressure gauge
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	17	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 12/2: Circuit diagram

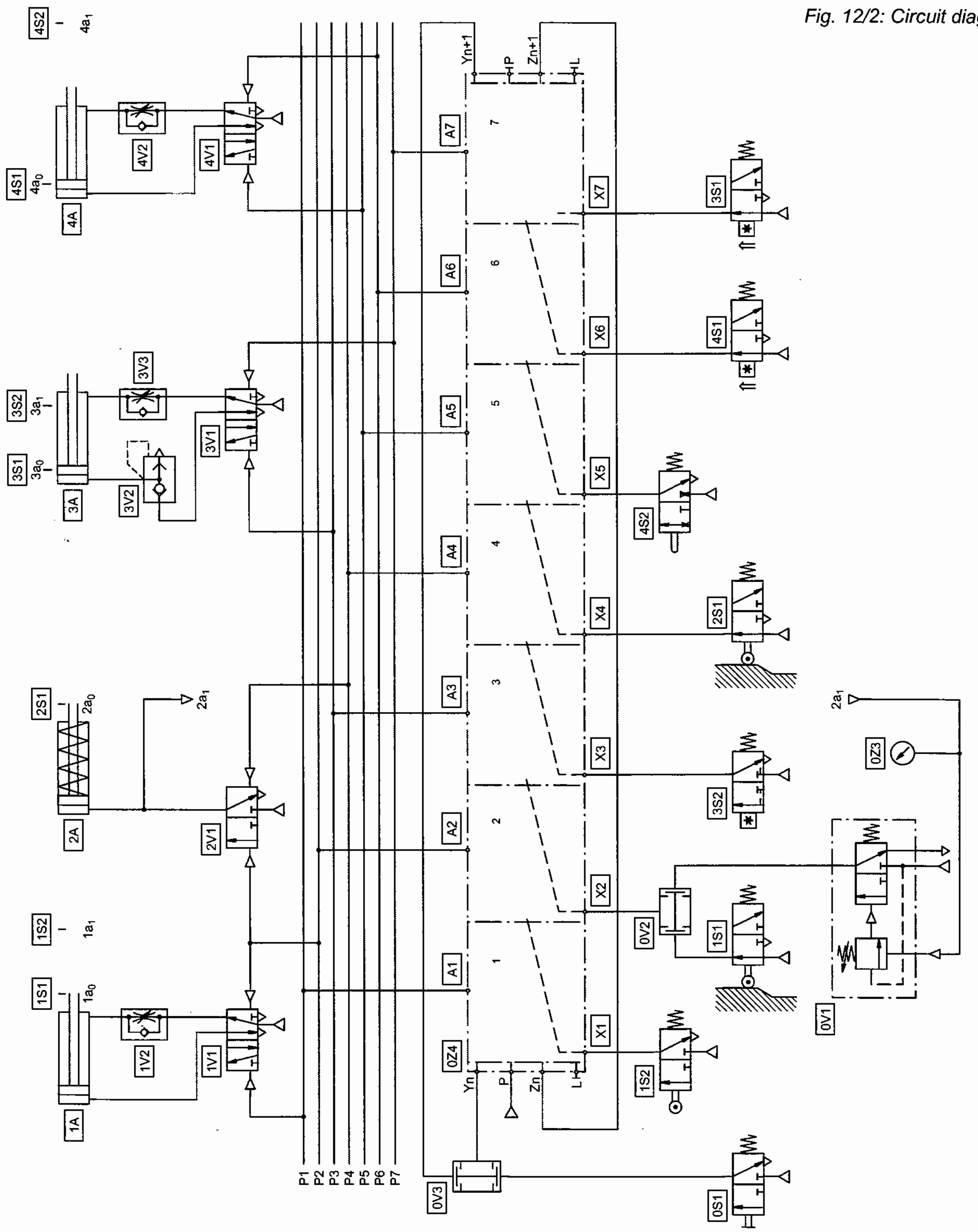
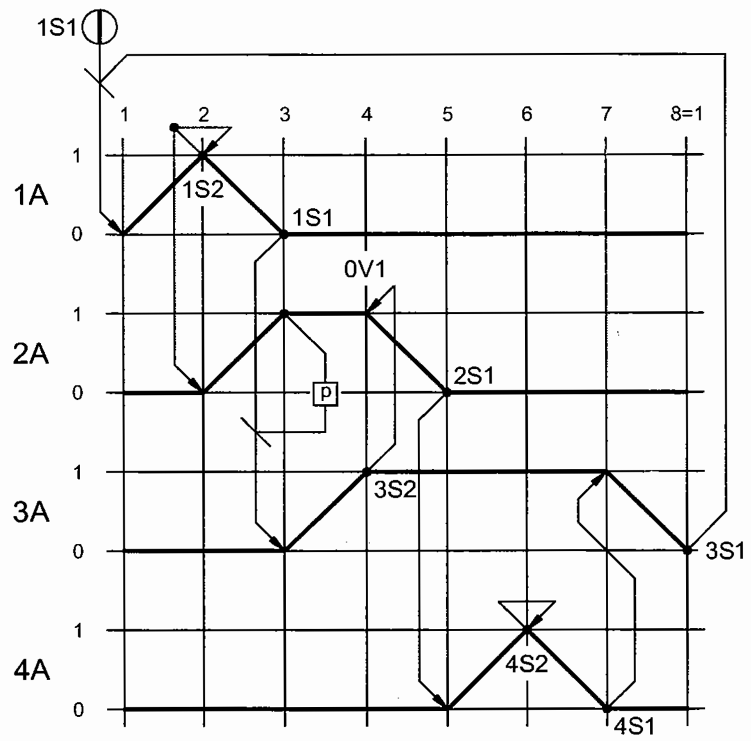


Fig. 12/3: Displacement-step diagram



Solution description

Initial position

The actuators are located in their retracted end position. Sensors (1S1), (2S1), (3S1) and (4S1) are actuated.

Step 1-2 –
Transfer cylinder (1A) pushes the housing onto the parts carrier (1A+).

The processor is activated via the START signal of the valve (0S1). The output signal A1 of the first module (type A) reverses the final control element (1V1). The transfer cylinder (1A) travels into its forward end position and actuates the roller lever valve (1S2).

Step 2-3 –
Clamping cylinder (2A) clamps housing (2A+); transfer cylinder (1A) retracts (1A-).

The acknowledgement signal for movement 1A+ sets the second module (type A) of the sequencer. Output signal A2 reverses the final control elements (1V1) and (2V1). Cylinder (2A) extends. The cylinder (1A) returns to its retracted end position and actuates roller lever valve (1S1).

Step 3-4 –
Transfer cylinder (3A) transports the housing through the washing cabin (3A+).

Movement 1A- is acknowledged by the roller lever valve (1S1). A signal is applied to port 14 of the dual pressure valve (0V2). As soon as sufficient pressure has built up in the clamping cylinder (2A), the pressure sequence valve (0V1) switches through. Now pressure is also applied to port 12 of the AND gate (0V2). The third module (type A) of the sequencer is set. Its signal A3 reverses the final control element (3V1). The cylinder (3A) travels into its forward end position and actuates the proximity switch (3S2).

Step 4-5 – Clamping cylinder (2A) releases the workpiece (2A-).

The acknowledgement signal of movement 3A+ switches to the fourth module (type A) via port X3. Its signal A4 reverses the final control element (2V1). The clamping cylinder (2A) travels into its retracted end position and actuates the roller lever valve (2S1).

Step 5-6 –
Cylinder (4A) pushes the housing onto the conveyor belt (4A+).

The acknowledgement signal of movement 2A- switches to the fifth module (type A) via port X4. Its signal A5 reverses the final control valve (4V1). Cylinder (4A) extends and actuates the back pressure valve (4S2).

Step 6-7 – Transfer cylinder (4A) retracts (4A-).

The acknowledgement signal of movement 4A+ switches to the sixth module (type A) via input X5. Its output signal A6 reverses the final control element (4V1). The cylinder (4A) travels into its retracted end position and actuates the pneumatic proximity switch (4S1).

Step 7-8 – Transfer cylinder (3A) retracts (3A-).

The acknowledgement signal of movement 4A- switches to the seventh module (type B) via input X6. Its output signal A7 reverses the final control element (3V1). The cylinder (3A) travels into its retracted end position and actuates the pneumatic proximity switch (3S1). The 3/2-way pneumatic valve of the seventh module reverses. Its continuous signal Yn+1 is applied to the dual-pressure valve (0V3). A renewed START signal starts the new cycle.

Note regarding the circuit design

The sequence control for the cleaning plant comprises seven steps. Up to eight steps are possible with two stepper modules. The idle step (in this case step 5, signal from output A5 to input X5) can be connected as required to steps 1 to 7.

The following applies when bridging steps:

- Last step must not be an idle step
- Two idle steps may not be switched in sequence

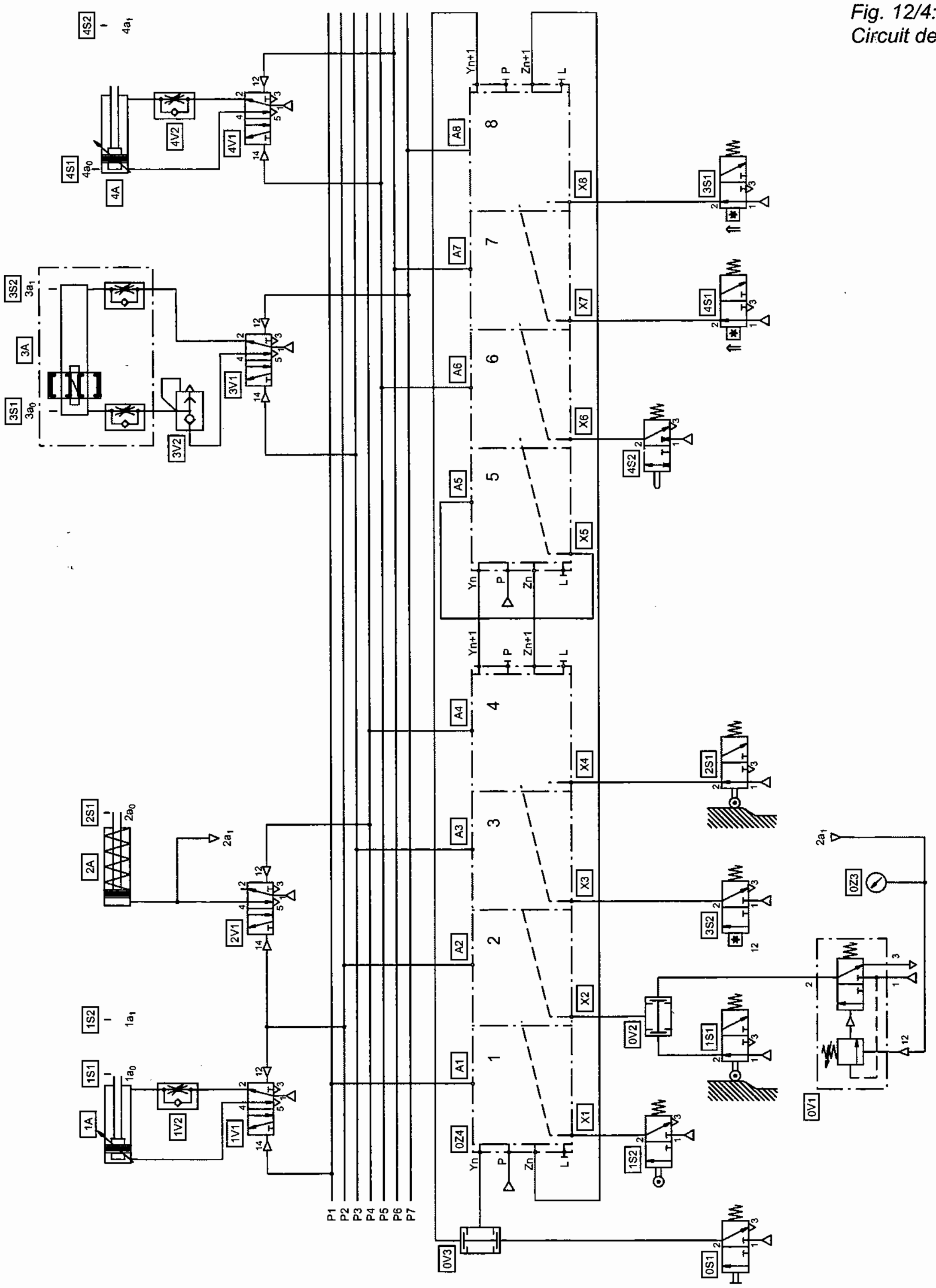


Fig. 12/4:
Circuit design

Fig. 12/2:
Extended circuit diagram
(Part 1)

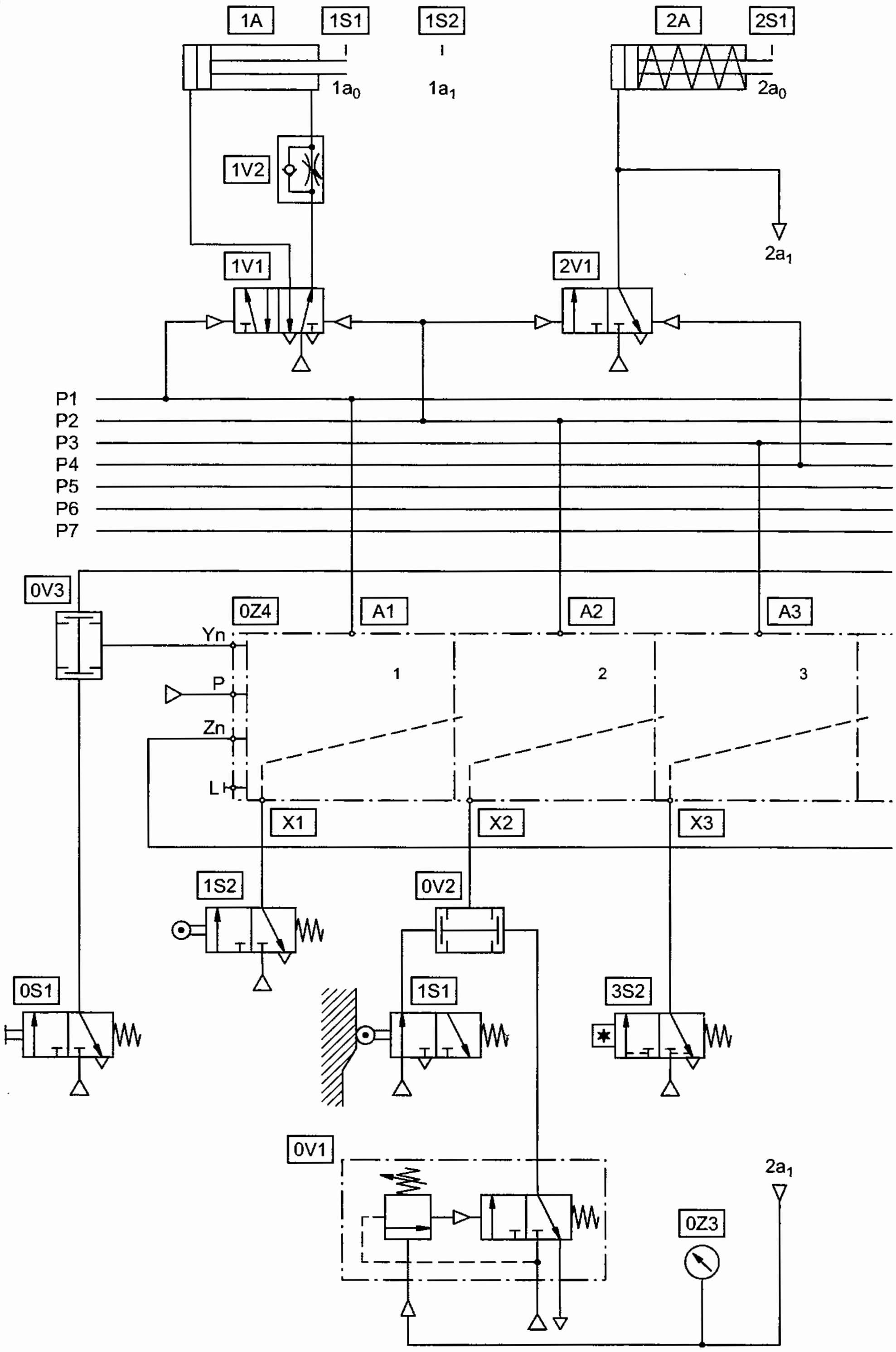
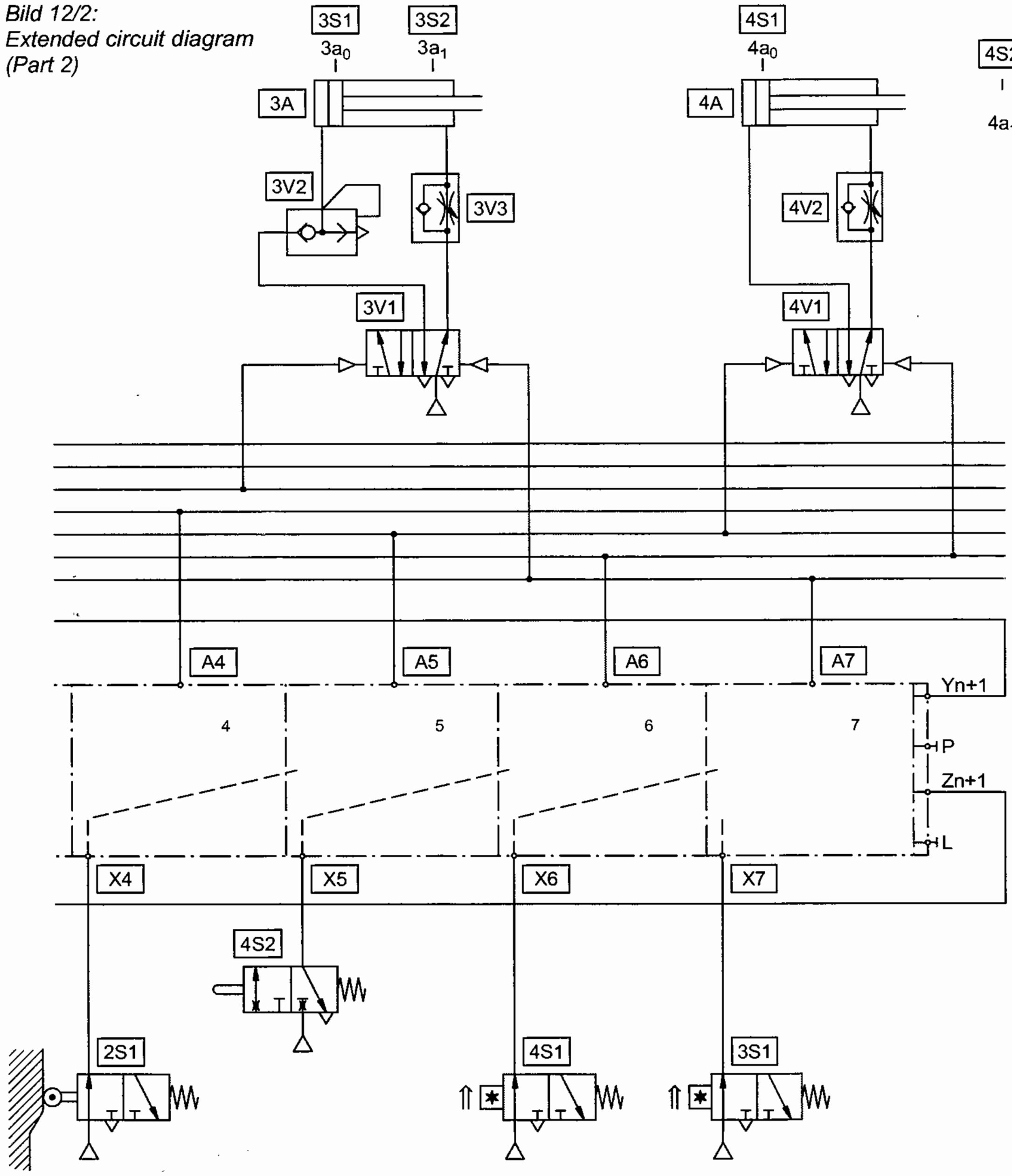


Bild 12/2:
Extended circuit diagram
(Part 2)



Flat grinding machine

Notes on procedure

Components to be used

- Identify the valves and their tasks using a soft pencil or self-adhesive labels.
- Connect up the ports of the stepper modules as described in exercise 12. As stated in exercise 9, a sensor (proximity switch (2S1) and (2S2) respectively) activates two steps simultaneously. Only the step currently set passes on the signal.
- 5/2-way pneumatic double pilot valves are to be used to form the memories (2V4) and (2V5), and, as described previously, the working ports 2 are to be plugged. Check each time whether the required function has been achieved.
- Component (0V4) is the pressure sequence valve.
- Functions

START button	(0S1)
EMERGENCY-STOP mushroom actuator	(0S2)
RESET button	(0S3)

Basic pressure: at pressure sequence valve (0V4) 3 bar (300 kPa).

Self-latching is obtained via the shuttle valve (0V1) following the START signal. A continuous signal is produced via the lefthand side of (0V1) to port 12 from valve (0V2), and via (0V2) and (0V3) and the righthand side of (0V1).

RESET is only possible if the EMERGENCY-STOP has previously been actuated.

EMERGENCY-STOP: Valve (0S2) resets the memory (0V3) via the EMERGENCY-STOP signal, whereby the self-latching signal (0V2) is cancelled.

START can only take place when the EMERGENCY-STOP (0S2) is unlatched.

Safety aspects: see “Further development”.

Components list

Components	*Quantity*	*Designation*
1A	1	Single-acting cylinder
2A, 3A	2	Double-acting cylinder
2V7, 2V8	2	One-way flow control valve
1V2, 2V4, 2V5, 2V6, 3V2	5	5/2-way double pilot valve
0V1, 1V1, 2V1, 2V2, 2V3, 3V1	2	Shuttle valve, 3-fold
0V5, 0V6	1	Dual-pressure valve, 3-fold
0V2, 0V3	2	3/2-way pneumatic valve, convertible
0S2	1	3/2-way valve with mushroom actuator, red, norm. closed
0S1, 0S3	2	3/2-way valve with push button, normally closed
1S2	1	Back pressure valve
1S1, 3S1, 3S2	3	3/2-way roller lever valve, normally closed
2S1, 2S2	2	Pneumatic proximity switch
1Z1	1	Pressure gauge
0V4	1	Pressure sequence valve
0Z3	1 1	Stepper module Stepper module, extension
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	26	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

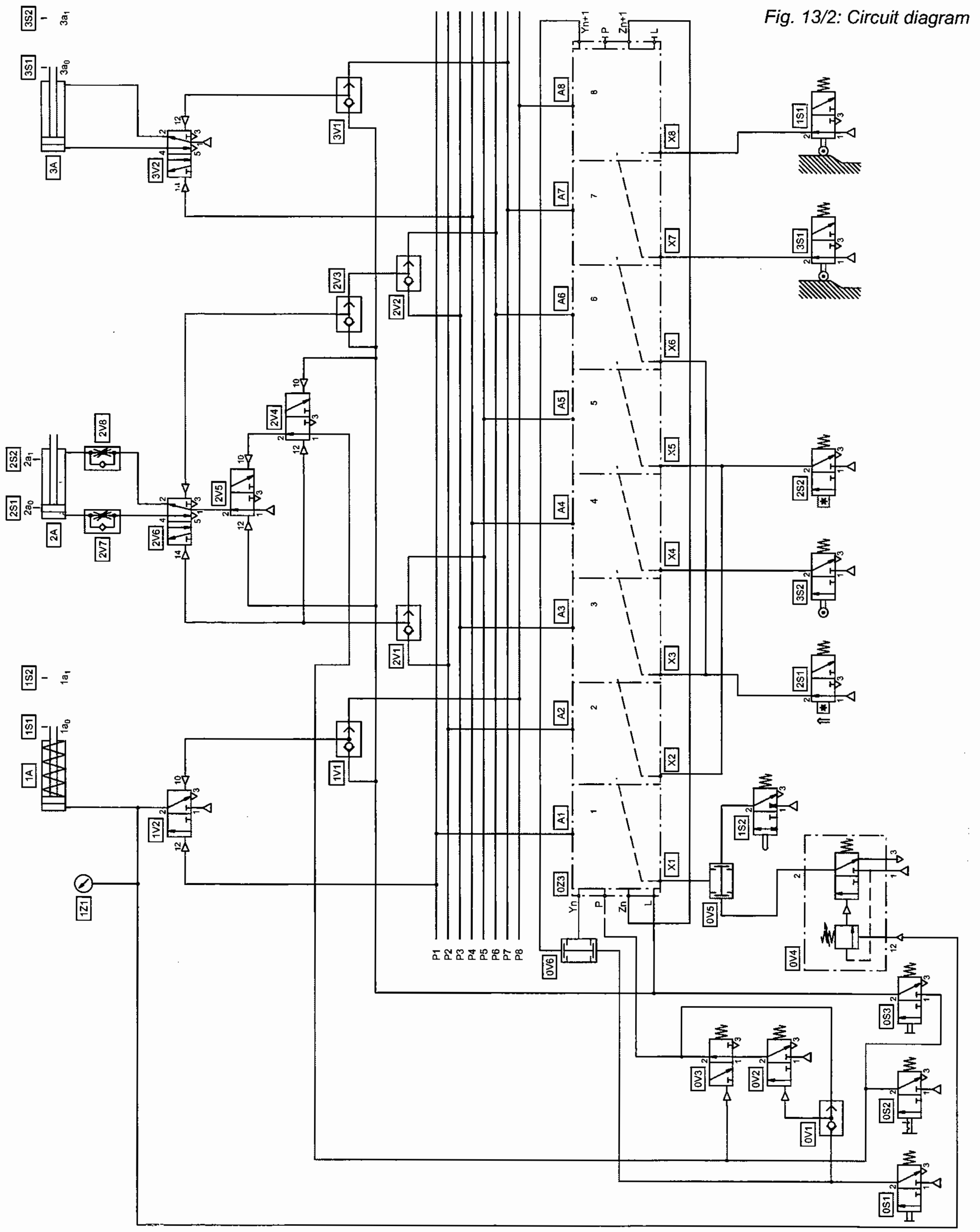
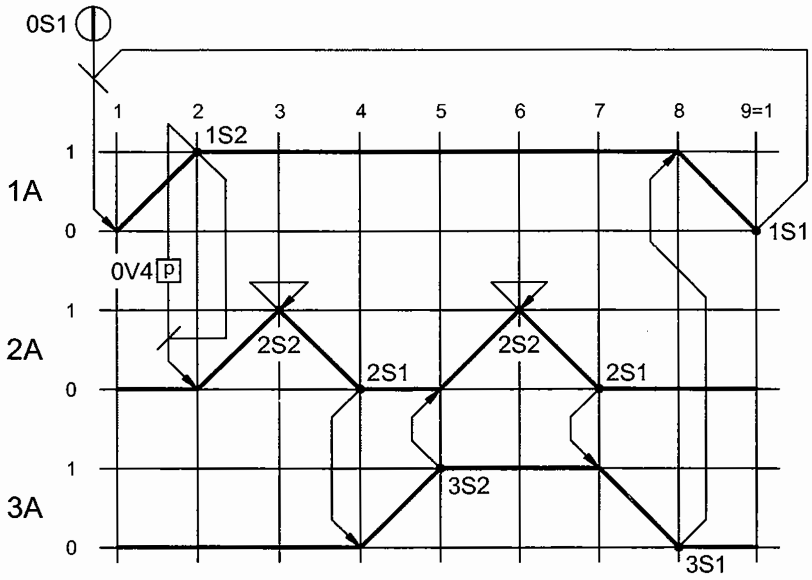


Fig. 13/2: Circuit diagram

Fig. 13/3: Displacement-step diagram



Solution description

Initial position

The actuators are in their retracted end positions. Sensors (1S1), (2S1) and (3S1) are actuated. Memory valves (2V4), (2V5) and the 3/2-way pneumatic valve (0V3) have throughflow. The self-latching valve (0V2) is in normally closed position.

Step 1-2 – Cylinder (1A) clamps the workpiece (1A+).

Following the START signal (0S1) the sequencer is pressurised via the self-latching circuit of valves (0V1), (0V2) and (0V3). The same signal sets the first module of the sequencer via port Y. Signal A1 reverses the final control element (1V2). The cylinder (1A) extends and actuates the back pressure valve (1S2).

Step 2-3 – Feed cylinder (2A) extends (2A+).

As soon as a pressure of p = 4 bar (400 kPa) has built up in the piston chamber of the cylinder (1A), the pressure sequence valve (0V4) switches. The second module is set via connection X1, together with the acknowledgement signal for the movement 1A+. Signal A2 reverses the final control element (2V6) and cylinder (2A) extends. In its forward end position, it actuates the proximity switch (2S2).

Step 3-4 – Feed cylinder (2A) retracts (2A-).

The acknowledgement signal for movement 2A+ sets the third module via port X2 (this signal is also applied to port X5, but cannot, however switch through to the sixth module since the fifth module is not set). Signal A3 reverses the final control element (2V6) via shuttle valves (2V2) and (2V3). The cylinder (2A) retracts and actuates the pneumatic proximity switch (2S1) in its retracted end position.

Step 4-5 – Cylinder (3A) transfers the workpiece (3A+).

The acknowledgement signal for movement 2A- sets the fourth module via input X3 (module 7 cannot be activated via X6). Its signal A4 reverses the final control element (3V2). The cylinder (3A) extends and actuates the roller lever valve (3S2).

Step 5-6 und 6-7 –
Cylinder (2A) carries out its second double stroke (2A+) and (2A-).

The acknowledgement signal for movement 3A+ sets the fifth module via port X4. Its signal A5 reverses the signalling element (2V6). Cylinder (2A) extends and actuates the proximity switch (2S2). Since the fifth module has now been set, the signal at port X5 is only to activate the sixth module. Signal A6 controls the return of cylinder (2A) into its retracted end position, where it actuates the proximity switch (2S1).

Step 7-8 – Cylinder (3A) travels into its initial position (3A-).

The acknowledgement signal for movement 2A- sets the seventh module via port X6. Its signal A7 reverses the final control element (3V2). Cylinder (3A) retracts and actuates the roller lever valve (3S1) in its retracted end position.

Step 8-9 – Cylinder (1A) unclamps the workpiece (1A-).

The acknowledgement signal from movement 3A- sets the eighth module (type B) via port X7. Its signal A8 reverses the final control element (1V2). Cylinder (1A) is exhausted and actuates the roller lever valve (1S1) in its retracted end position. A continuous signal Yn+1 is once again supplied to dual-pressure valve (0V6). A renewed START signal will then initiate the next cycle.

Marginal conditions

- **EMERGENCY-STOP**
  Actuation of the EMERGENCY-STOP mushroom actuator first of all exhausts valve (0V3). The self-holding circuit is broken. Thus the compressed air supply to the sequencer is interrupted. The 3/2-way pneumatic valve (0V2) assumes the normally closed position. The 3/2-way pneumatic valve (2V5) is reversed via the memory valve (2V4). The compressed air supply for cylinder (2A) is interrupted. Both cylinder chambers are exhausted.
- **RESET**
  When the EMERGENCY-STOP valve (0S2) is detented, the actuators and the processor can be set via the 3/2-way valve (0S3). Cylinders (1A), (2A) and (3A) once again assume their initial position. If valve (0S2) is actuated, a new cycle can be introduced via a START signal.

Further development

Safety aspects are to be discussed here by means of examples.
It is difficult to reconstruct the step sequence since the cycle is executed very quickly. Delays may be achieved by throttling all cylinder inlets and outlets or manually operating the signal elements 1S2, 1S2, 3S1 and 3S2, when the cylinder has carried out the step required for this.

- The EMERGENCY-STOP mushroom actuator is manually operated.
- Observe its behaviour during each step.
  Is the solution for cylinder 2A - exhaust air control - feasible?
- EMERGENCY-STOP (0S2) is actuated whilst:

  Step 1-2: Clamping cylinder (1A) completes the stroke

  Step 2-3: Feed cylinder (2A) stops in principle, but the residual pressure pushes it a little bit further

  Step 3-4: As step 2-3

  Step 4-5: Cross feed cylinder (3A) travels into the forward end position

  Step 5-6: As step 2-3

  Step 6-7: As step 3-4

  Step 7-8: Cross feed cylinder (3A) travels into the retracted end position

  Step 8-9: Clamping cylinder (1A) travels into the retracted end position

Conclusion

Cylinder (2A), which determines the feed of the workpiece, is controlled on both sides in spite of exhaust air flow restriction. Since the cutting force also affects the air cushion and influences the feed in that slowing down occurs at the start of the cutting process and a jump at the end of the process, constant feed is not possible.

Solution

Use hydraulic cushioning cylinders as in exercise 4.

Safety aspects of an uninterrupted cycle

Question 1: What is the purpose of valves (0V4) and (1S2)?

Question 2: What happens if the clamping force drops and the feed actuator (2A) and cross feed cylinder (3A) move?

Question 3: Is it certain that the actuator (2A) is stationary, while cross feed cylinder (3A) executes the traversing movement of the workpiece so that the grinding wheel does not get caught on the workpiece?

Answer to 1

Valve (1S2) ensures that clamping cylinder (1A) has advanced. Valve (0V4) checks that the clamping pressure has built up, i.e. the clamping position (0V5) and the clamping pressure have been reached before sequencing is allowed to continue (response to setpoint changes).

Answer to 2

Provided the second step has already been completed, the whole of the remainder of the cycle is executed. In case of incorrect pressure, the sequencer is to be interrupted only during step 1 via the dual-pressure valve in accordance with the diagram.

Conclusion regarding 2

The manual EMERGENCY-STOP circuit (0S2) is to be completed with the addition of an automatic EMERGENCY-STOP circuit (see below).

Answer to 3

Cross feed cylinder (2A) is controlled via proximity switches, which is why a sliding transition replaces a precide switching point. Consequently, (3A) might already start during the return stroke of (2A) and thus cause a collision.

Solution to 3

The proximity switches on (2A) are to be replaced by roller lever valves. Cylinder (3A) is to be delayed by time elements or possibly one-way flow control valves or (2A) requires a correspondingly large overtravel.

Extend the circuit to encompass automatic EMERGENCY-STOP

i.e. EMERGENCY-STOP is introduced as soon as the clamping pressure drops.

Solution 1

The clamping pressure for this circuit is conducted via the pressure sequence valve (0V4) to the dual-pressure valve (0V5). Each input signal X of the sequencer is to be linked to "AND" via a dual-pressure valve. Sequencing only takes place when the previous step has been completed and the clamping pressure is applied.

Disadvantage: Cylinders (2A) and (3A) complete the step, which has been started.

Solution 2

In the marginal conditions section, self-latching (0V1), (0V2) and (0V3) is to be interrupted by EMERGENCY-STOP (0S2) acting on (0V3) as previously manually, or in the event of loss of clamping pressure. As the equipment set does not contain all the required components, this solution is not considered in more detail. It also has the same disadvantage as solution 1.

Solution 3

Immediate stop of all movements with drop of clamping pressure. The pressure source upstream of (3V2) and (2V5) is jointly exhausted abruptly by a 3/2-way pneumatic valve activated by the clamping pressure causing a complete standstill.

Fig. 13/2:
Extended circuit diagram
(Part 1)

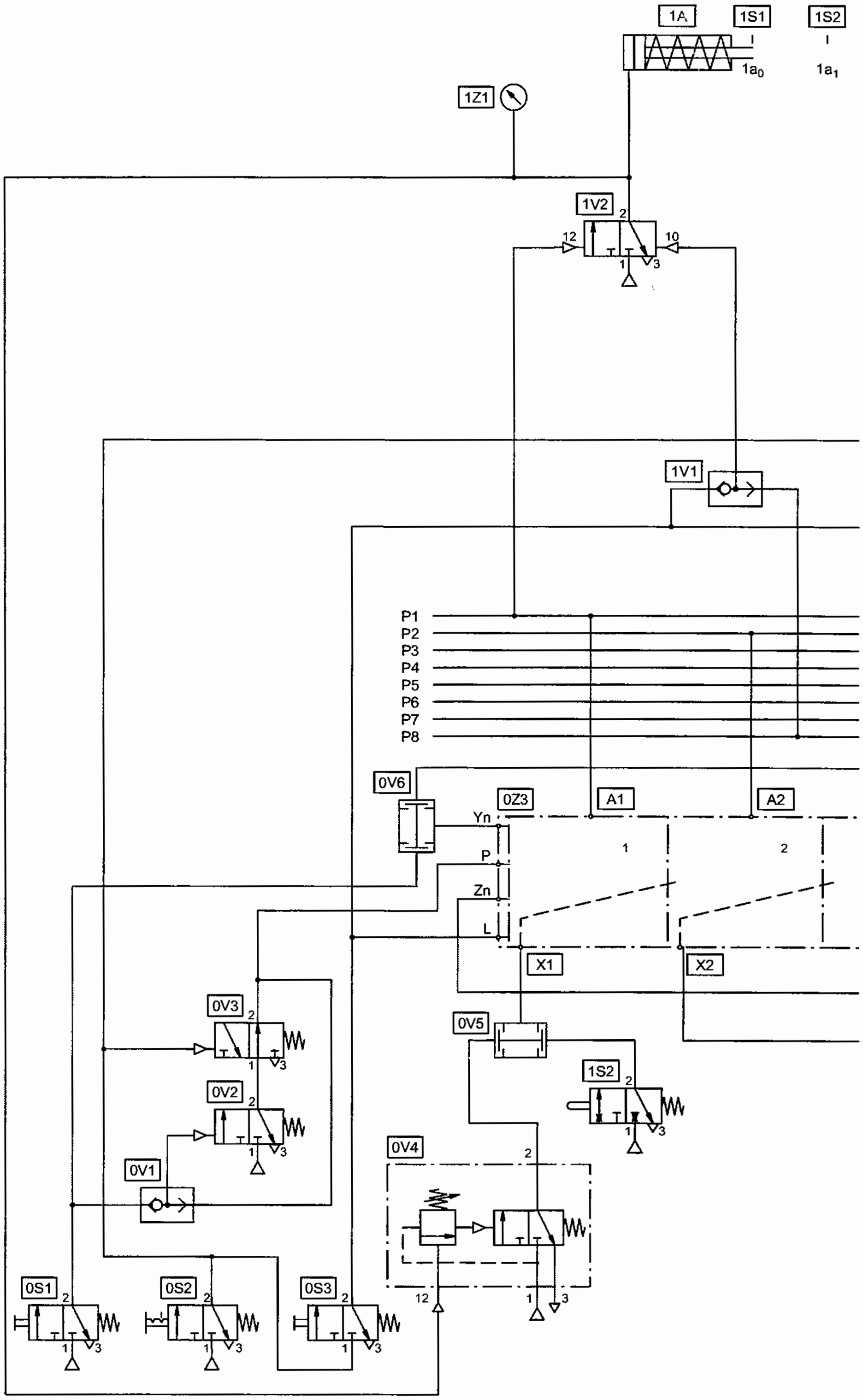
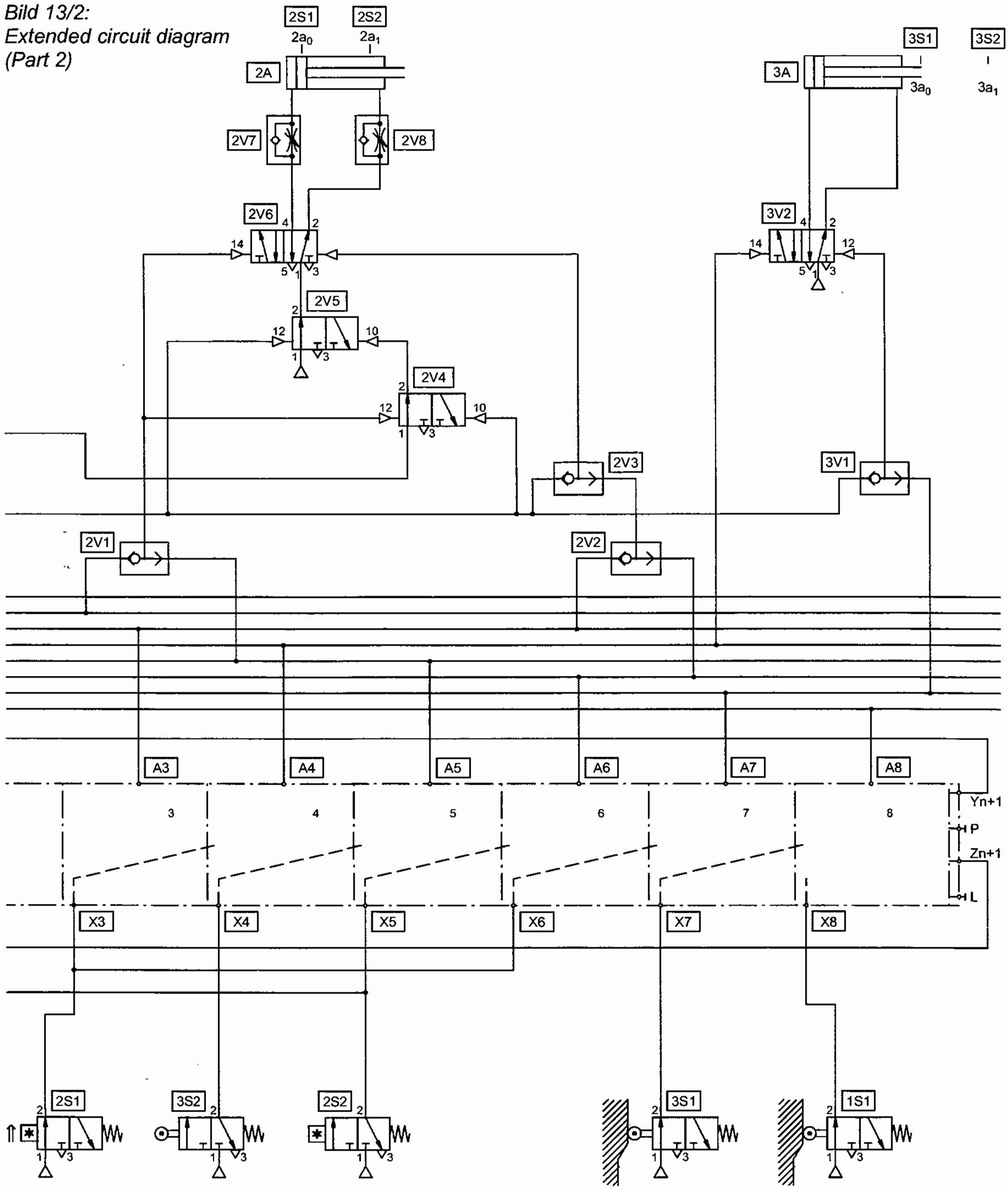


Bild 13/2:
Extended circuit diagram
(Part 2)



Solution 13

Stocking device

Notes on procedure

Components

- The cylinder with hollow piston rod (1A) is to be replaced on the profile plate by a double-acting cylinder.
- The vacuum suction generator with suction cup (3A) is to be arranged as a separate unit. The adjustable vacuum actuator (0V4) must not be confused with the pressure sequence valve, which has an almost identical symbol.
- Label the valves immediately using a soft pencil or self-adhesive labels.
- The lines which have been connected up can be crossed off on a copy of the circuit diagram.
- The final control element (3V2) must be constructed from a 5/2-way valve. Likewise, the memory (0V7).
- 3/2 valves (0V2), (0V3) and (0V5) can be made from 5/2-way pneumatic valves.
- The two one-way flow control valves (2V3) and (2V4) will not be required for the purpose of the practical circuit construction since the linear drive (2A) is already equipped with two one-way flow control valves.

Start conditions

- Once you have fully constructed the control circuit, it is first necessary to set the sequencer.
- The counter (0V6) is to be set to "3" strokes, otherwise the problem might arise that you are looking for errors in the circuit when there is actually nothing wrong (because the counter is set at "0").

Start

1. Actuate EMERGENCY-STOP.
2. Actuate RESET.
3. Unlatch EMERGENCY-STOP.
4. START

To restart, it is sufficient to reactuate the START button, whereby the counter resets itself automatically.

EMERGENCY-STOP

At the end of each step the system stops as the self-latching of P is interrupted via (0V2) and no further pressure is available to the sequencer to introduce the next step. Before unlatching EMERGENCY-STOP and actuating START, you need to RESET the controller (0S2), i.e. return the actuator and processor sections to their initial position.

Components list

Components	*Quantity*	*Designation*
1A	1	Double-acting cylinder
2A	1	Linear drive, pneumatic
3A	1	Vacuum generator/suction cup
0V2, 0V3, 0V5	3	5/2-way pneumatic valve
1V5, 1V6	2	One-way flow control valve
0V7, 1V4, 2V2, 3V2	4	5/2-way double pilot valve
0V1, 1V1, 1V2, 1V3, 2V1, 3V1	2	Shuttle valve, 3-fold
0V8	1	Dual-pressure valve
1S1, 1S2	2	3/2-way roller lever valve, normally closed
2S1, 2S2	2	Pneumatic proximity switch
0S1	1	3/2-way valve with mushr. actuator, red, norm. closed
0S2, 0S3	2	3/2-way valve with push button, normally closed
0V4	1	Adjustable vacuum actuator
0V6	1	Pneumatic preselect counter
0Z3	1 1	Stepper module Stepper module, extension
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	26	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

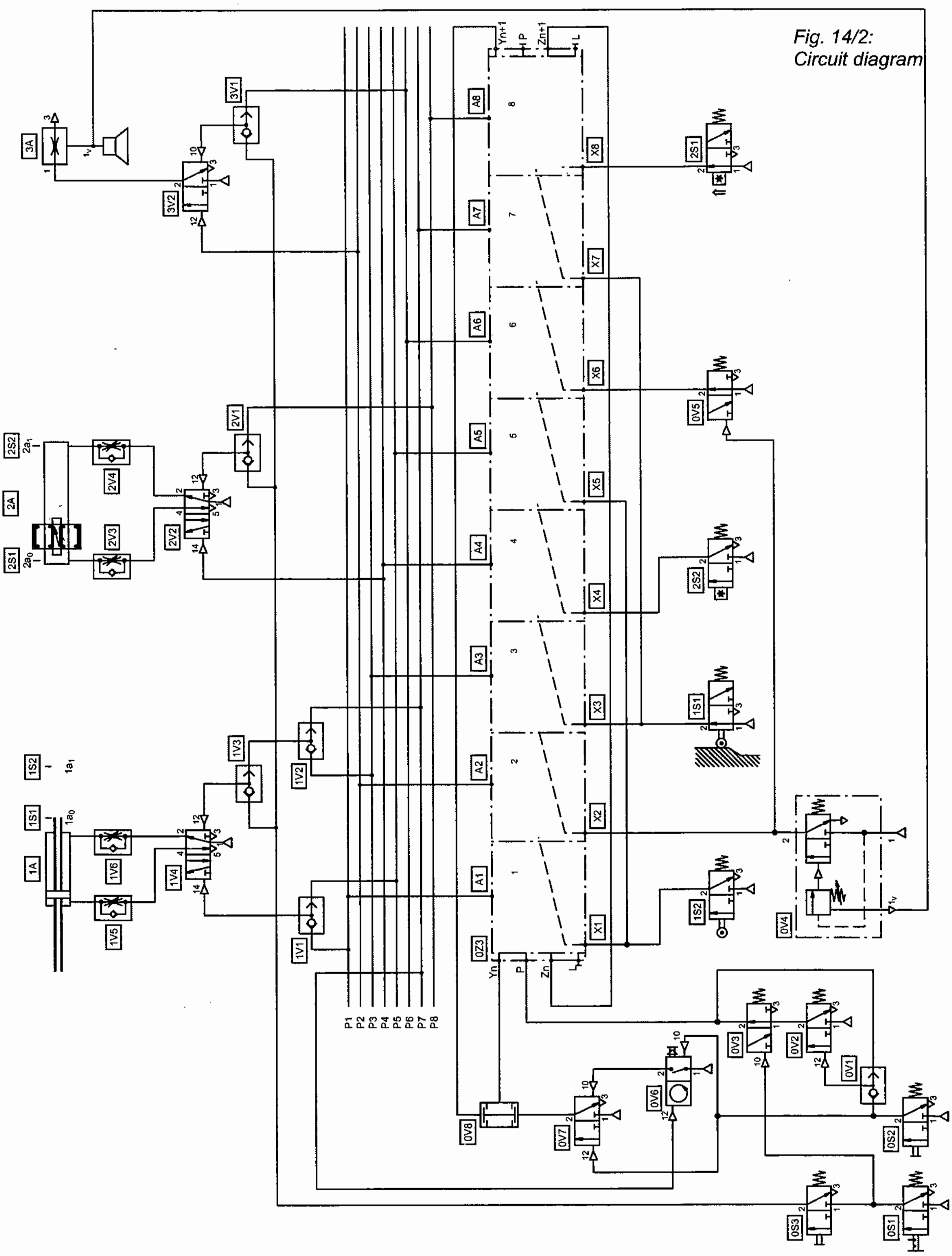
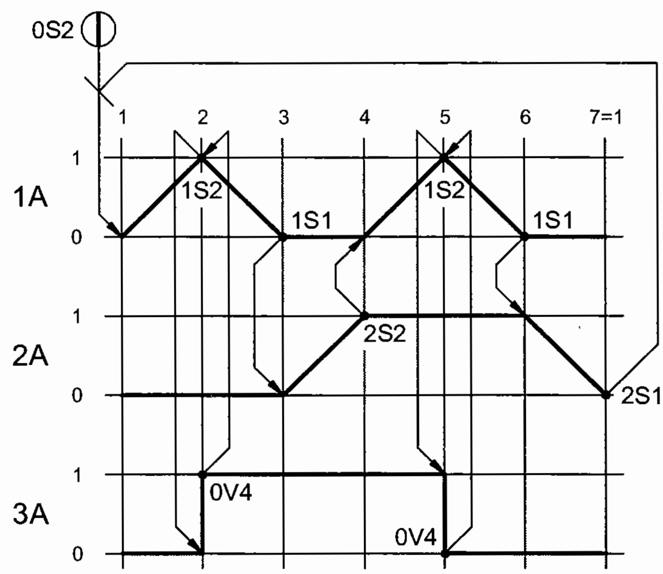


Fig. 14/2:
Circuit diagram

Fig. 14/3: Displacement-step diagram



Solution description

Initial position

Cylinders (1A) and (2A) are located in their lefthand end positions. The vacuum generator (3A) is switched off. The pneumatic preselect counter (0V6) is set to three counting signals. The processing section is reset, i.e. signal Yn+1 is applied to the dual-pressure valve (0V8). Sensors (1S1) and (2S1) are actuated.

Step 1-2 – Lifting cylinder (1A) extends (1A+).

The processing section is supplied with compressed air by the START signal (0S2) via the self-latching circuit valve (0V1), (0V2), (0V3). In the same way, valve (0V7) is switched to flow. The first module of the sequencer is set via the dual-pressure valve (0V8). Its signal A1 reverses the final control element (1V4) via the shuttle valve (1V1). The cylinder (1A) extends with exhaust air throttled and actuates the roller lever valve (1S2).

Step 2-3 –
Vacuum generator generates vacuum (3A+),
lifting cylinder (1A) lifts up a package (1A-).

The second module is set by the acknowledgement signal for movement 1A+. Its signal A2 reverses the final control element (3V2). Compressed air flows through the vacuum generator. As soon as the suction cup contacts a bar of soap, a vacuum is generated in the line to the valve (0V4). The adjustable vacuum actuator switches the attached basic valve to flow. Its output signal sets the third module of the sequencer via port X2. Signal A3 reverses the final control element (1V4) via shuttle valves (1V2) and (1V3). The cylinder (1A) retracts and actuates the roller lever valve (1S1) in its retracted end position.

Step 3-4 – Transfer cylinder (2A) travels to the right (2A+).

The acknowledgement signal from movement 1A- switches through to the fourth module. Its output signal A4 reverses the final control element (2V2). Cylinder (2A) travels into its righthand end position with exhaust air throttled and actuates the pneumatic proximity switch (2S2).

Step 4-5 – Lifting cylinder (1A) lowers the soap into the box (A+).

The acknowledgement signal from movement 2A+ switches through to the fifth module. Its output signal A5 reverses the final control element (1V4) via shuttle valve (1V1). Cylinder (1A) extends and actuates the roller lever valve (1S2) in its forward end position.

Step 5-6 –
Vacuum generator (3A) is switched off (3A-),
lifting cylinder (1A) retracts (A-).

The acknowledgement signal from movement 1A+ now switches the sequencer to the sixth module via port X5. Its signal A6 exhausts the final control element (3V2). A vacuum thus no longer exists at the suction cup and thus also at port 1_V of the adjustable vacuum actuator (0V4). The built-in 3/2-way valve assumes the normally closed position. The pneumatic valve (0V5) switches to normally open position. A continuous signal is applied at X6 and the seventh module is set. Its output signal reverses the final control element (1V4) via shuttle valves (1V2) and (1V3). The cylinder (1A) retracts and actuates the roller lever valve (1S1). A counting signal reaches the pneumatic preselect counter (0V6) via line P7. If this has reached the zero position in the third cycle, its output signal switches the memory valve (0V7) to normally closed position. The cycle is concluded. A renewed START signal resets the counter to three cycles and the 5/2-way double pilot valve (0V7) is switched to flow.

Step 6-7 –
Transfer cylinder (2A) travels to the left (2A-).

The acknowledgement signal from movement 1A- switches the sequencer to the eighth module. Its signal A8 reverses the final control element (2V2) via the shuttle valve (2V1). The cylinder (2A) travels into its lefthand end position and actuates the pneumatic proximity switch (2S1). The continuous signal Yn+1 is once again applied to the dual-pressure valve (0V8). If the preselect counter (0V6) has not yet reversed the memory valve (0V7), a new cycle begins immediately.

Marginal conditions

- **EMERGENCY-STOP**
  Actuation of the EMERGENCY-STOP mushroom actuator switches off the compressed air supply to the processor via the 3/2-way pneumatic valve (0V3). The self-latching circuit is interrupted. The pneumatic valve (0V2) assumes the normally closed position. The cylinders complete the movements they have started. The vacuum generator remains either switched on or off.
- **RESET**
  If the EMERGENCY-STOP valve (0S1) is detented, the actuating section and the processor can be reset via valve (0S3). Cylinders (1A) and (2A) travel into their initial positions. The vacuum generator is switched off. Signal Yn+1 of the eighth module (type B) of the sequencer is once again applied to the dual-pressure valve (0V8). If the valve (0S1) is detented, a new cycle can be started.

0,

Fig. 14/2:
Extended circuit diagram
(Part 1)

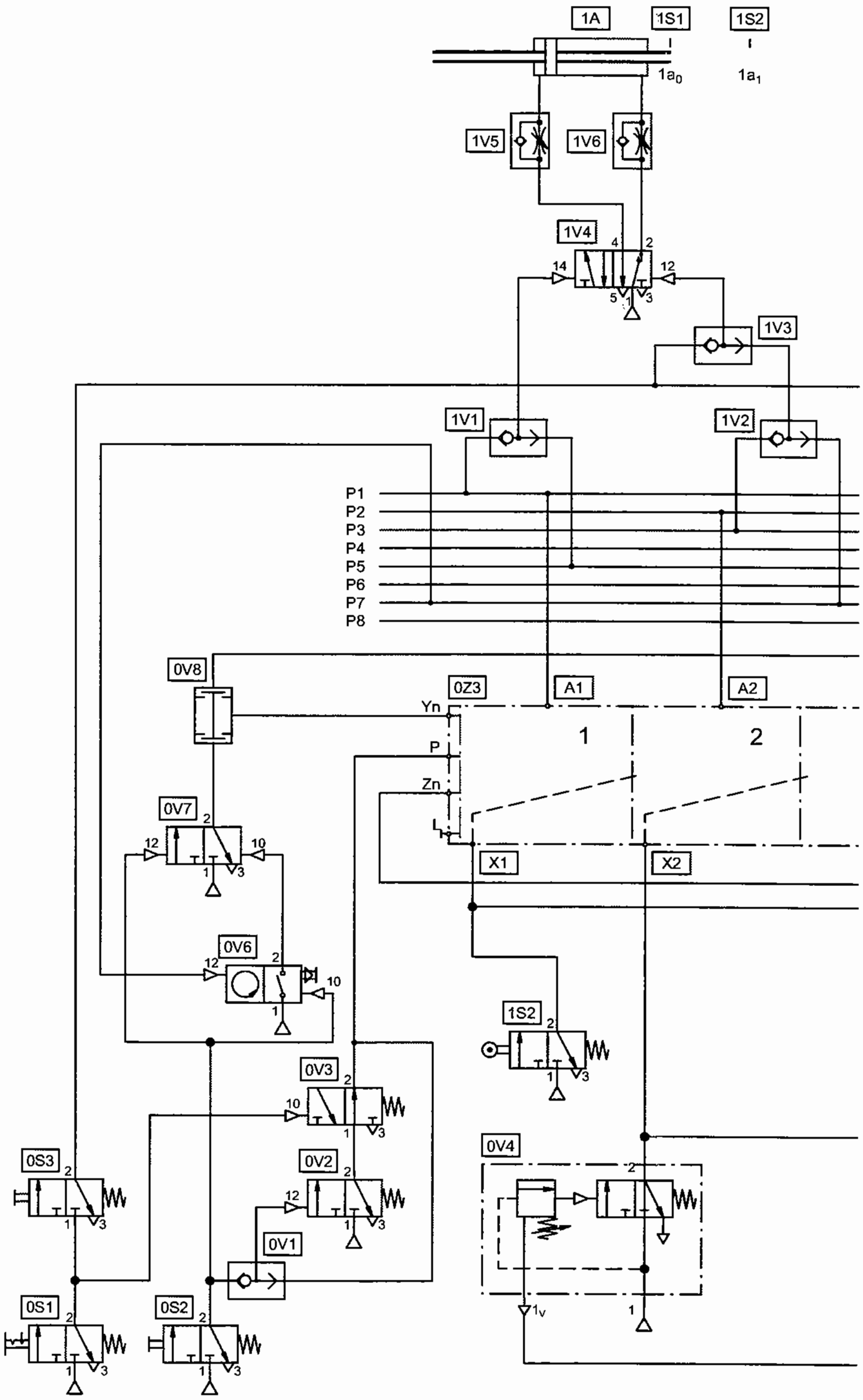
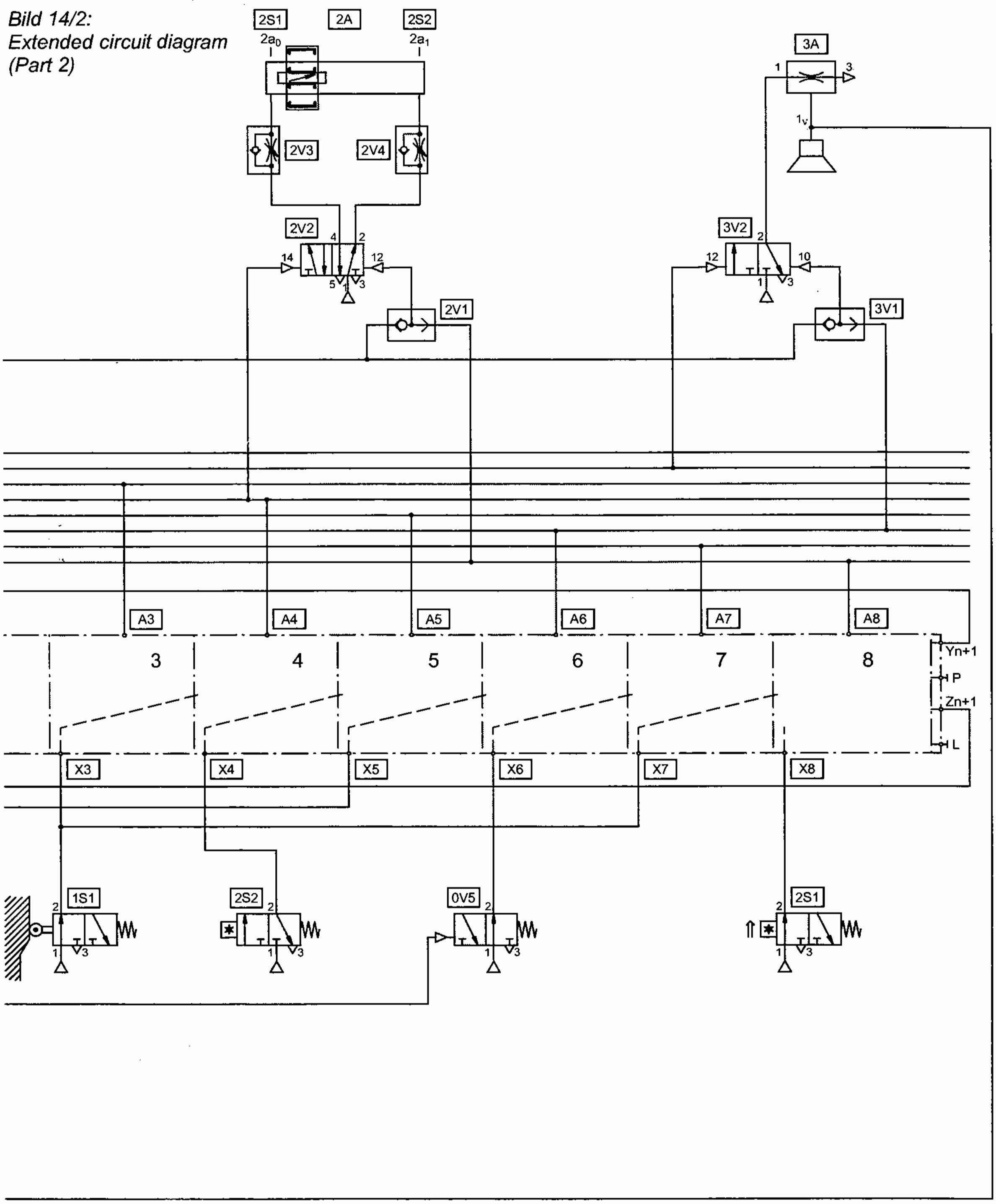


Bild 14/2:
Extended circuit diagram
(Part 2)



Separation of packages of varying heights

Notes on procedure

Simulation of parcel height

This exercise is similar to exercise 14. Only the packages vary in height. Simultation of varying package heights can be achieved by sensing the suction generator at varying extending positions of cylinder (1A). The roller lever valve (1S2) is only activated when packages are deposited, whereupon the suction effect is interrupted (command variable control).

Components

- The two one-way flow control valves (2V3) and (2V4) are not required for the practical circuit construction, since the linear drive (2A) is equipped with two one-way flow control valves.
- The usual setting problems arise with signal elements (1S1), (1S2), (2S1) and (2S2).
- 3/2-way valves (0V3) and (0V2) must be formed by converting 5/2-way valves.
- Ensure that symbol (0V4) represents the adjustable vacuum actuator as in exercise 14.

Programs

The programs will only run correctly if the suction simulation has been carried out correctly. If, for example, you immediately contact a surface with the suction generator, steps 1 to 3 are suppressed and cylinder (2A) immediately starts to advance.

EMERGENCY-STOP

Provided EMERGENCY-STOP is actuated, the step which has been introduced will be executed at the end. A new START is not possible until after RESETTING.

Components list

Components	Quantity	Designation
1A	1	Double-acting cylinder
2A	1	Linear drive, pneumatic
3A	1	Vacuum generator/suction cup
0V1	1	Shuttle valve
0V2, 0V3	2	5/2-way pneumatic valve
0V5, 1V1	2	3/2-way pneumatic valve, convertible
0V7	1	Dual-pressure valve
0V6, 1V2, 1V3, 1V4, 2V1, 3V1	2	Shuttle valve, 3-fold
1V6, 1V7	2	One-way flow control valve
1V5, 2V2, 3V2	3	5/2-way double pilot valve
0S1	1	3/2-way valve with mushr. actuator, red, norm.closed
0S2, 0S3	2	3/2-way valve with push button, normally closed
0S4	1	5/2-way valve with selector switch
1S1, 1S2	2	3/2-way roller lever valve, normally closed
2S1, 2S2	2	Pneumatic proximity switch
0V4	1	Adjustable vacuum actuator
0Z3	1 1	Stepper module Stepper module, extension
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	24	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 15/2:
Circuit diagram

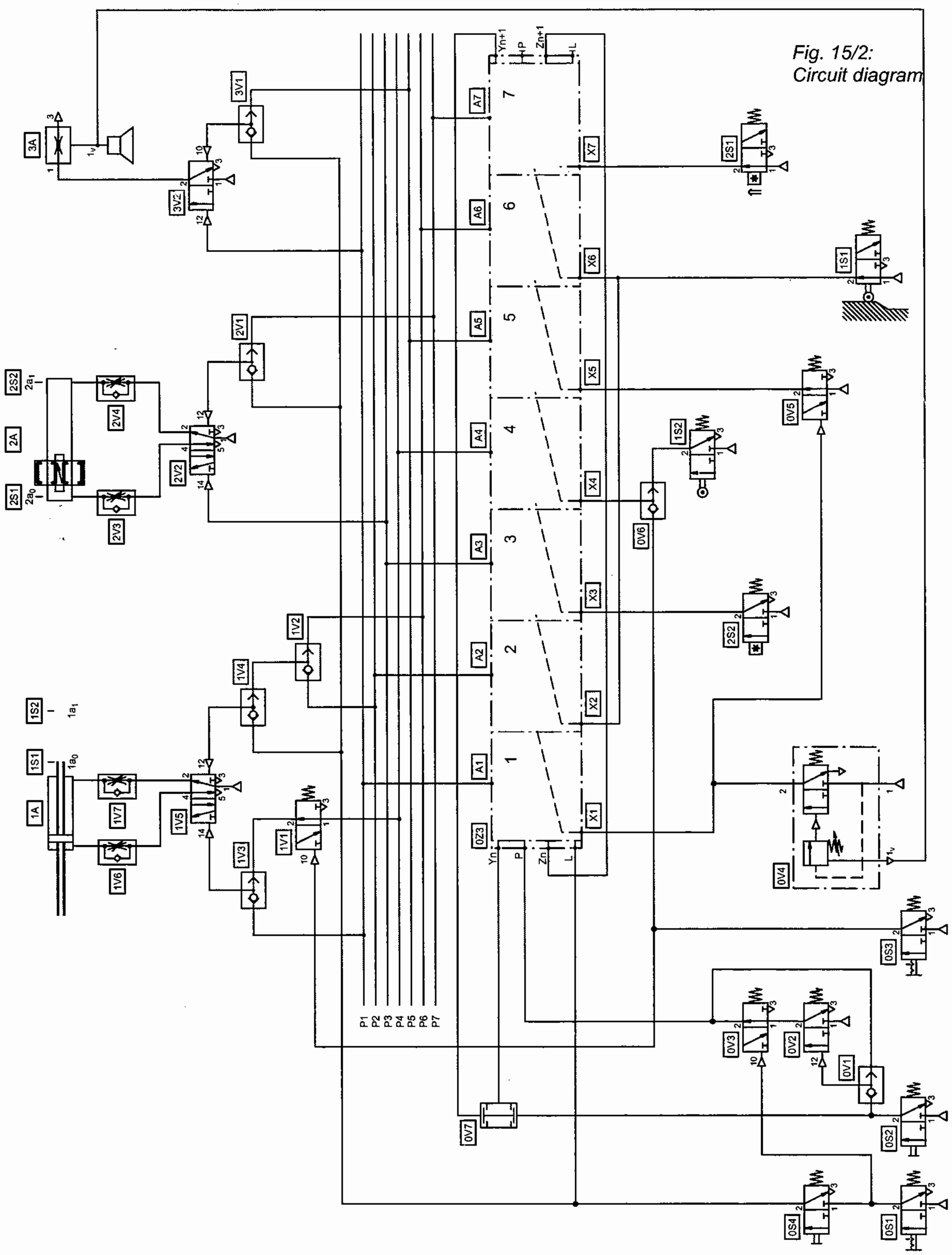


Fig. 15/3:
Displacement-step diagram (Program I)

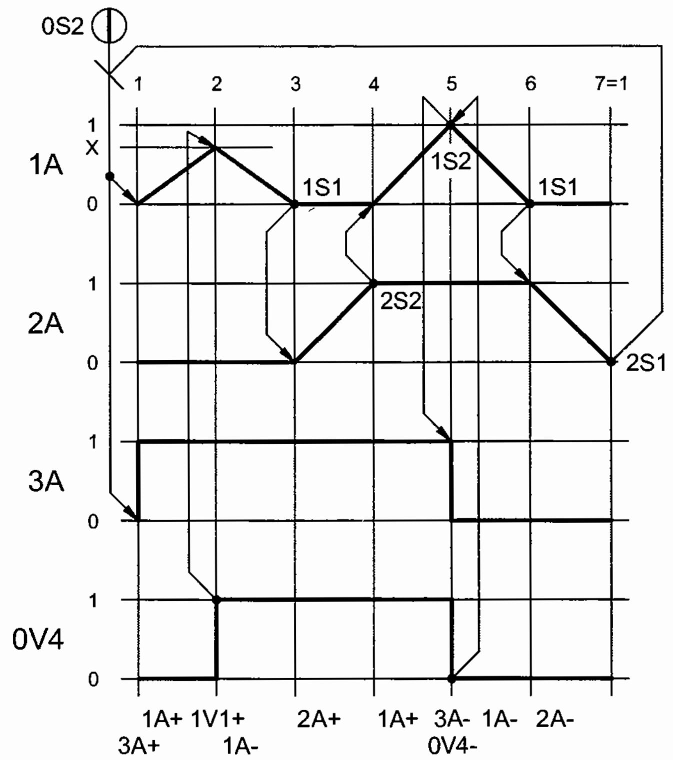
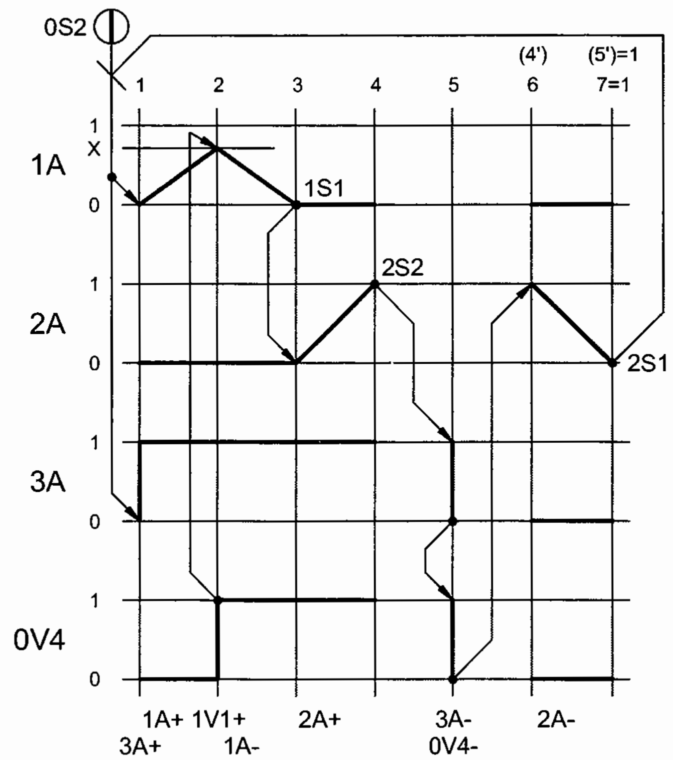


Fig. 15/4:
Displacement-step diagram (Program II)



Solution description

Initial position

Cylinders (1A) and (2A) are located in their retracted end position. The suction generator (3A) is switched off. Sensors (1S1) and (2S1) are actuated. Pneumatic valve (0V2) in the self-latching circuit is in the normally closed position. The selector switch of valve (0S4) is switched to program I.

PROGRAM I

Step 1-2 –
Lifting cylinder (1A) extends (1A+), Vacuum suction cup (3A) operates.

The stepper modules are supplied with compressed air by the START signal (0S2) via the self-latching circuit of valves (0V1), (0V2) and (0V3). The same signal sets the first stepper module via port Y. Its output signal simultaneously reverses the final control elements (1V5) and (3V2). Cylinder (1A) extends considerably throttled with suction cup in operation. If the suction cup comes into contact with a package, then the adjustable vacuum actuator (0V4) switches (response to setpoint changes of the suction cup). The acknowledgement signal of the vacuum actuator (0V4) then sets the second module at port X1. Pneumatic valve (0V5) is also actuated. Its output signal is applied to X5 provided the adjustable vacuum actuator has not switched.

Step 2-3 – Lifting cylinder (1A) lifts package (1A-).

Signal A2 of the second module reverses the final control element (1V5) via shuttle valves (1V2) and (1V4). The lifting cylinder (1A) returns throttled into its retracted end position and actuates the roller lever valve (1S1).

Step 3-4
Transfer cylinder (2A) travels across the measuring device (2A+).

The acknowledgement signal for movement (1A-) sets the third module via port X2. The resulting signal A3 reverses the final control element (2V2). Transfer cylinder (2A) travels into its righthand end position and actuates the pneumatic proximity switch (2S2).

Step 4-5 – Lifting cylinder (1A) extends (1A+).

The acknowledgement signal for movement 2A+ sets the fourth module. Signal A4 reverses the final control element (1V5) via valves (1V3) and (1V1); the lifting cylinder extends and actuates the roller lever valve (1S2).

Step 5-6 –
Suction cup (3A) releases the package,
lifting cylinder (1A) retracts (1A-).
The acknowledgement signal for movement 1A+ sets the fifth module. Its signal A5 reverses the final control element (3V2). The vacuum generator is exhausted. Thus, a signal is no longer applied to the adjustable vacuum actuator. The pilot line to valve (0V5) is exhausted. Valve (0V5) assumes the normally closed position. A continuous signal is now applied to port X5. The sixth module is set and its signal A6 reverses the final control valve (1V5). Cylinder (1A) returns into its retracted end position and actuates the roller lever valve (1S1).

Step 6-7 –
Transfer cylinder (2A) travels across to the conveyor belt (2A-).

The acknowledgement signal for movement 1A- sets the seventh module. Its signal A7 reverses the final control element (2V2). The cylinder (2A) travels into its lefthand end position and actuates the pneumatic proximity switch (2S1). Signal X7 switches to the eighth module. Signal Yn+1 is once again applied to the dual-pressure valve (0V7). The next cycle can be introduced by means of a new START signal.

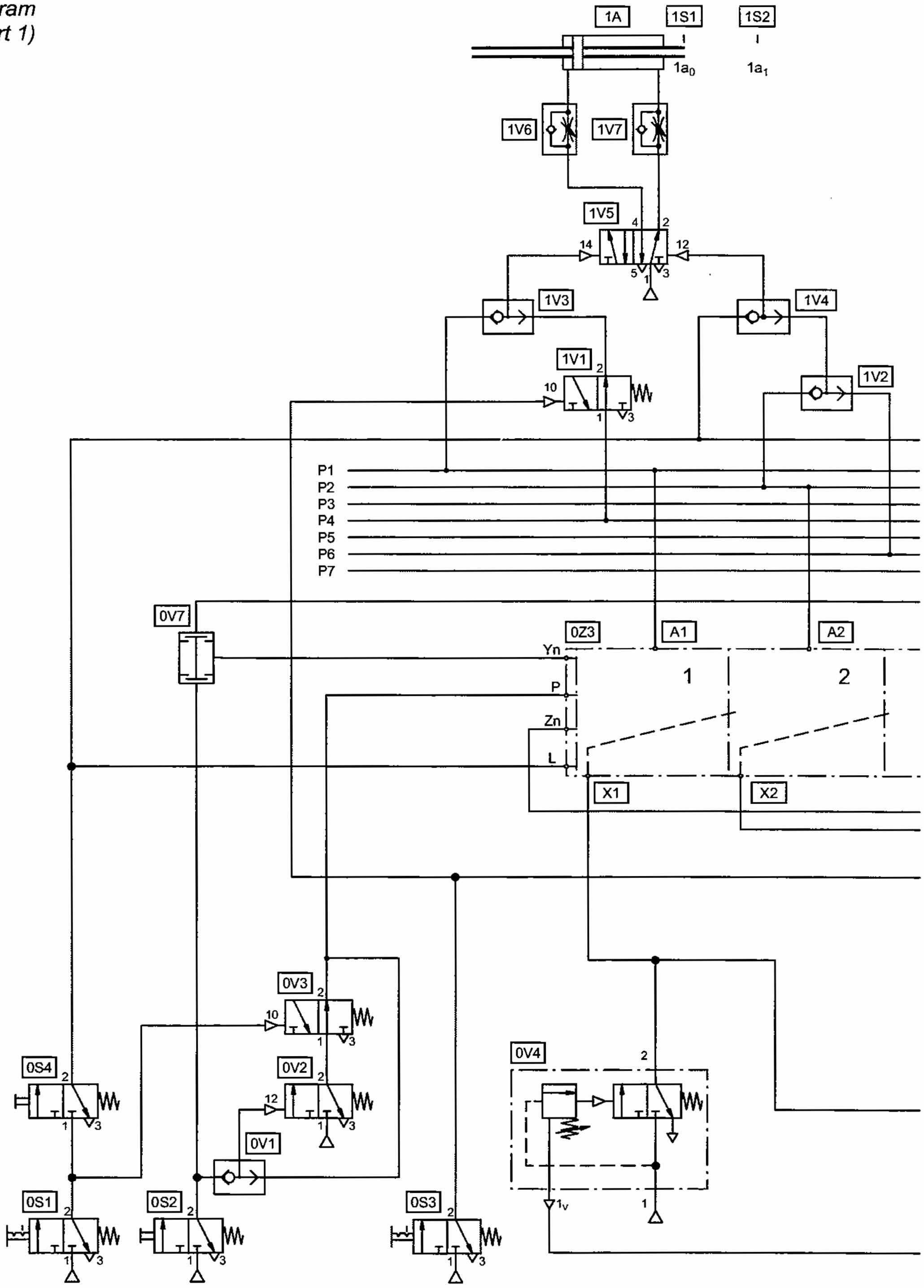
PROGRAM II **Steps 4-5 and 5-6 are omitted.**

If valve (0S3) is latched to program II, a continuous signal is applied to port X4 of the fourth module. Moreover, the 3/2-way pneumatic valve (1V1) is pressurised. If proximity switch (2S2) on the righthand side of the cylinder (2A) is actuated, cylinder (1A) will not be able to extend. Valve (1V1) blocks signal A4. However, the continuous signal of valve (0S4) is applied to port 4 in place of acknowledgement signal 1A+. The fifth module is set. Signal A5 exhausts the pilot lines to valve (0V5). A continuous signal is applied to port X5. The seventh module is set. Step 6-7 can proceed.

Marginal conditions

- **EMERGENCY-STOP**
  Actuation of the EMERGENCY-STOP mushroom actuator (0S1) interrupts the compressed air supply for the processing section. The final control elements cannot be reversed. The actuators complete their current movement.
- **RESET**
  When the EMERGENCY-STOP (0S1) is actuated, the processing section can be reset via valve (0S4) via port L. Final control elements (1V5) and (2V2) are switched to flow from 1-2. Thus, the cylinders assume their retracted end and lefthand positions. Final control element (3V2) exhausts the vacuum generator. If the EMERGENCY-STOP valve (0S1) is unlatched, a new cycle can be started.

Fig. 15/2:
Extended circuit diagram
(Part 1)



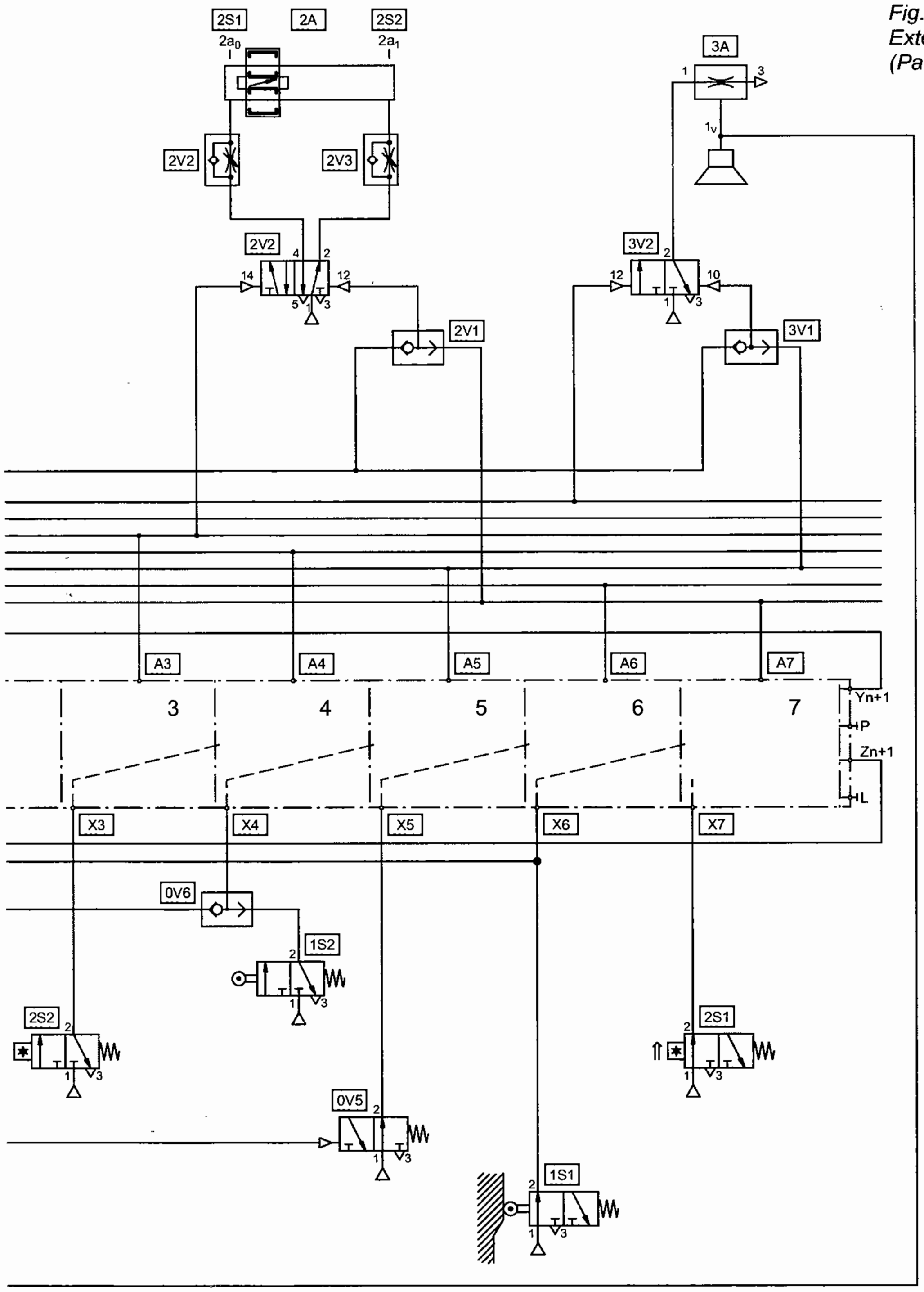


Fig. 15/2:
Extended circuit diagram
(Part 2)

Transfer line with gravity feed magazine and two stations

Notes on procedure

The more complex the program, the more confusing it can become and the more likely it is to make mistakes.

General information

Identify each valve immediately (circuit diagram number)! Specify each switching position, e.g. AUTOMATIC/MANUAL. Reduce the stroke speed of cylinders by installing additional one-way flow control valves to make it easier to determine the step sequence.

Cylinders

Instead of the two single-acting cylinders (2A1) and (2A2), it is also possible to work with just one actuator. Two proximity switches are required for linear drive (1A). These cannot be replaced by other sensors. The two one-way flow control valves (1V3) and (1V4) will not be required for the practical circuit construction as the linear drive (1A) is equipped with two one-way flow control valves. Cylinder (3A) can also be sensed by means of three roller lever valves and can thus replace proximity switch (3S3).

Impulse ejector (5A) (see also components list)

This component function can be equally well demonstrated using a loose piece of tubing. With a short reaction time of the time delay valve (5V1) a short, sharp pulse is emitted which causes maximum “effect”, particularly at a pressure of 4 bar (even if the pulse did not have to eject heavy parts).

Note that loose tubing flaps about and can therefore cause accidents! Use a short piece of tubing (20 cm maximum).

A better hardware solution would be a combination of a double-acting cylinder (as volumetric reservoir) and a quick exhaust valve. However, the integrated silencer at the outlet of the quick exhaust valve cushions the ejector pulse so powerfully that it can scarcely be recognised. Of course, it is also possible to use an impulse ejector supplied by Festo KG (industrial equipment, see components list).

Final control elements

Convert valves (2V2) and (5V3) by plugging ports.

Signalling elements

Check that these “switch”!

Stepper modules

Connect up stepper modules correctly! Component (0Z4): X2 to A2 and X4 to A4. Ensure correct fault finding procedure! Do not just check inputs X and outputs A, but also check air supply to P, Y, Z and L.

Components list

Components	Quantity	Designation
1A	1	Linear drive, pneumatic
2A1, 2A2	2	Single-acting cylinder
3A, 4A	2	Double-acting cylinder
5A*	1	Impulse ejector
0V1, 0V2	1	Dual-pressure valve, 3-fold
5V2	1	Shuttle valve
1V1, 2V1, 3V1, 3V2, 3V3, 4V1	2	Shuttle valve, 3-fold
1V2, 2V2, 3V4, 4V2, 5V3	5	5/2-way double pilot valve
0S1, 0S3, 0S5	3	3/2-way valve with push button, normally closed
0S2	1	3/2-way valve with selector switch, normally closed
0S4	1	5/2-way valve with selector switch
1S1, 1S2, 3S3	3	Pneumatic proximity switch
3S1, 3S2, 4S1, 4S2	4	3/2-way roller lever valve, normally closed
5V1	1	Time delay valve, normally closed
0Z5, 0Z6	2	Stepper module
0Z4	1	Stepper module, extension
0Z3	1	Memory module
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	32	Push-in T-connector

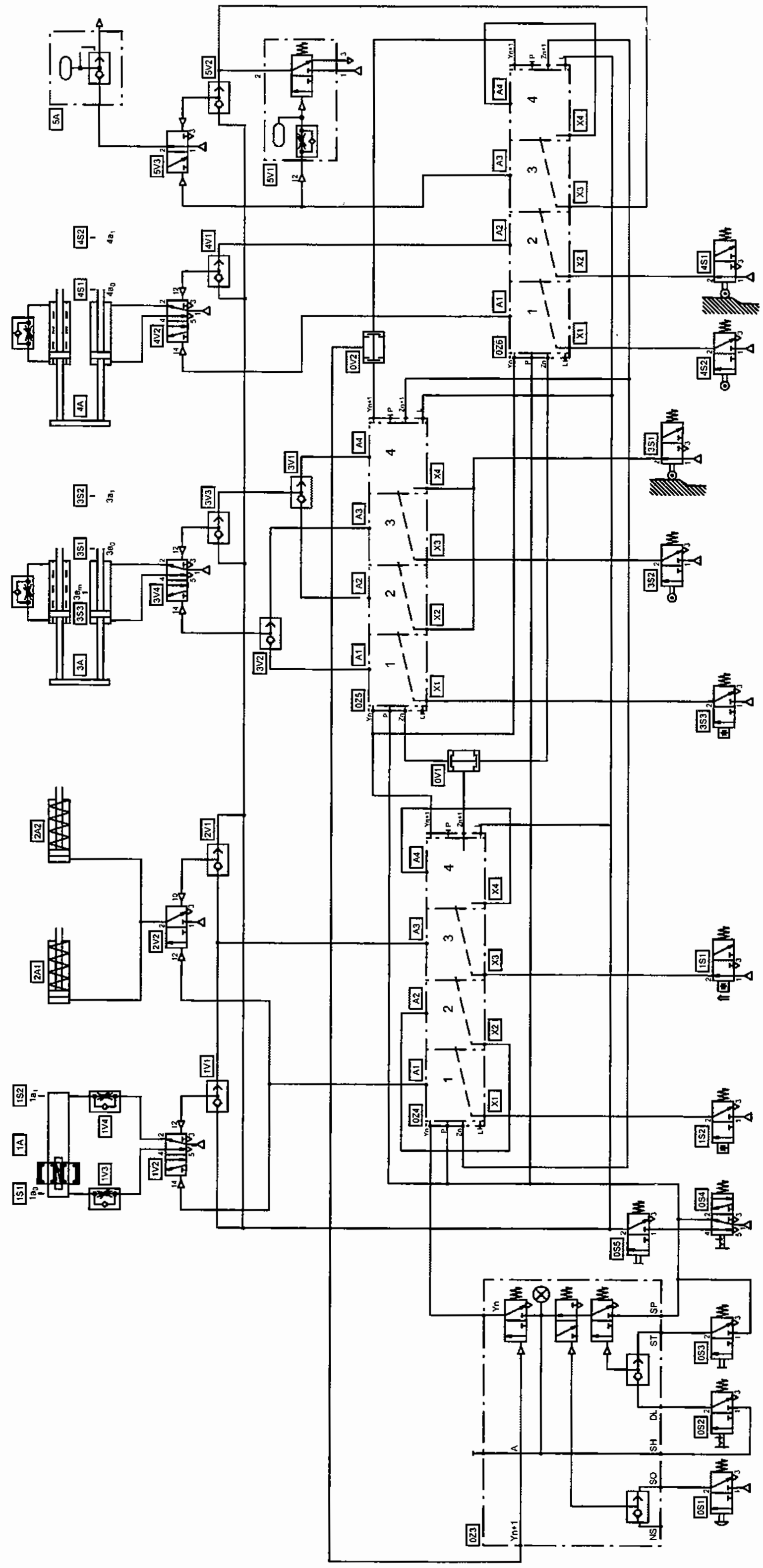
Components (0Z1) and (0Z2) are not shown in the circuit diagram.

* Re: component 5A: The impulse ejector is available from Festo AG & Co. in the form of an industrial component.

Simulation

- Quick exhaust valve from the equipment set of TP101 basic level plus large double-acting cylinder to act as a reservoir (volume).
- Or a short piece of tubing at the final control element. See also notes on procedure).

Fig. 16/3:
Circuit diagram



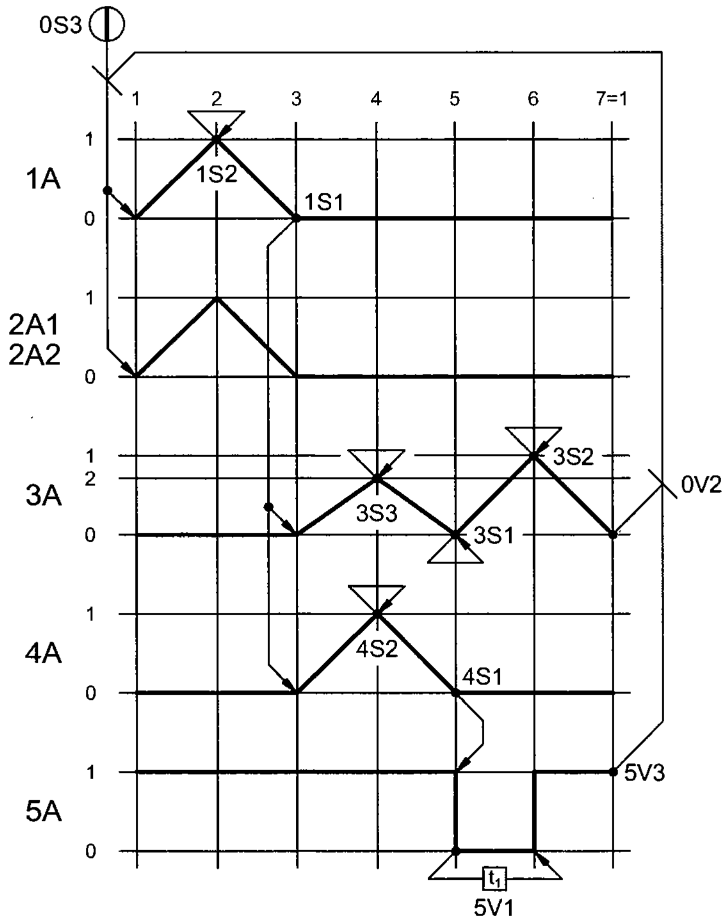


Fig. 16/4: Displacement-step diagram

Solution description

Initial position

The ejector cylinder (1A), the carrier cylinders (2A1) and (2A2) and feed units (3A) and (4A) are in their rectracted end positions. The impulse ejector (5A) is pressurised: The selector switch of the valve (0S4) is set to AUTOMATIC. Valve (0S2) is latched on SINGLE CYCLE.

Step 1-2 –
Transfer cylinder (1A), and carrier cylinder (2A1) and (2A2) extend (1A+, 2A1+, 2A2+).

The START signal from valve (0S3) passes to port Yn in the first stage of the sequencer (0Z4) and sets the first step (1-signal at output A1). At the same time, a signal is available at port Zn. The final stages are reset via ports Zn+1 in sequencers (0Z5) and (0Z6). Final control elements (1V2) and (2V2) are reversed by output signal A1. Transfer cylinder (1A) travels to the right (1A+) and actuates the proximity switch (1S2). Carrier cylinders (2A1) and (2A2) extend. The end positions are not sensed (because neither of the equipment sets contain the required number of sensors).

Step 2-3 – Cylinders (1A), (2A1) and (2A2) retract (1A-, 2A1-, 2A2-).

The acknowledgement signal for movement 1A+ is transmitted by sensor (1S2) to port X1 of the first stage of the sequencer (0Z4). The second module is reversed. This is short-circuited. Therefore, a 1-signal is immediately received at output A3. This signal once again reverses final control elements (1V2) and (2V2). Cylinders (1A), (2A1) and (2A2) carry out movement 1A-, 2A1- and 2A2-. Sensor (1S1) is actuated.

Step 3-4 –
Drilling station X performs a short stroke (3A+).
Drilling station Y performs a long stroke (4A+).

The acknowledgement signal for movement 1A- sets the fourth module via connection X3. This is once again short-circuited. Thus, the first module of the sequencer (0Z5) and (0Z6) is set via signal Yn+1. The last stage (module A) of the sequencer (0Z4) is reset via the dual-pressure valve (0V1). Signal A1 of the first module of sequencer (0Z5) reverses the final control element (3V4). Cylinder (3A) extends until sensor (3S3) is actuated.
Signal A1 of the sequencer (0Z6) reverses the final control element (4V2). The cylinder (4A) extends and actuates roller lever valve (4S2).

Step 4-5 –
The two drilling stations travel into their retracted end positions (3A-, 4A-).

The signal of sensor (3S3) activates the second module (sequencer module 0Z5). Signal A2 reverses the final control element (3V4). The cylinder (3A) travels into its retracted end position and actuates roller lever valve (3S1). The second module (0Z6) of the sequencer is set via the signal of the roller lever valve (4S2). Its output signal A2 reverses the final control element (4V2). The cylinder (4A) travels into its retracted end position and actuates the roller lever valve (4S1).

Step 5-6 –
Drilling station X performs a long stroke (3A+). The impulse ejector blows out the swarf (4A+).

The signal from the roller lever valve (3S1) sets the third module via port X2 of the sequencer (0Z5). The resulting output signal reverses the final control element (3V4). Cylinder (3A) advances and travels over sensor (3S3) (module 1 is reset) and actuates the roller lever valve (3S2). The signal from roller lever valve (4S1) sets the third module via port X2 of the sequencer (0Z6). First, its output signal A3 reverses the final control element (5V3) so that the impulse ejector exhausts and, secondly, the time delay valve (5V1) is supplied with air. When the set time (t = 2 sec) has elapsed, the final control element (5V3) is reset. This is switched to port X3 of the sequencer (0Z6). A Yn+1 singal is applied to the dual-pressure valve (0V2).

Step 6-7 – Drilling station X retracts (3A-).

The signal of the roller lever valve (3S2) sets the fourth module of the sequencer (0Z5). The final control element (3V4) is reversed via shuttle valves (3V1) and (3V3). The cylinder (3A) travels into its retracted end position and actuates roller lever valve (3S1). Now, two signals Yn+1 are applied to the dual-pressure valve (0V2). The input module is enabled for a renewed START signal.

CONTINUOUS CYCLE

If the selector switch of valve (0S2) is set to CONTINUOUS CYCLE, then a self-latching circuit is established in the input module. This can be broken by pressing the STOP button. The cycle then runs through to the end.

RESET

If valve (0S4) is set to MANUAL, then the 3/2-way valve (0S5) is supplied with compressed air. All the actuators and processors can be returned to their initial positions by means of actuation.

Further development

It should also be possible to manufacture workpieces on the transfer line, with a diameter of only 16 mm. An additional 5/2-way valve with detent is to be used for switching from program I to program II.

Solution 16

Fig. 16/3:
Extended circuit diagram
(Part 1)

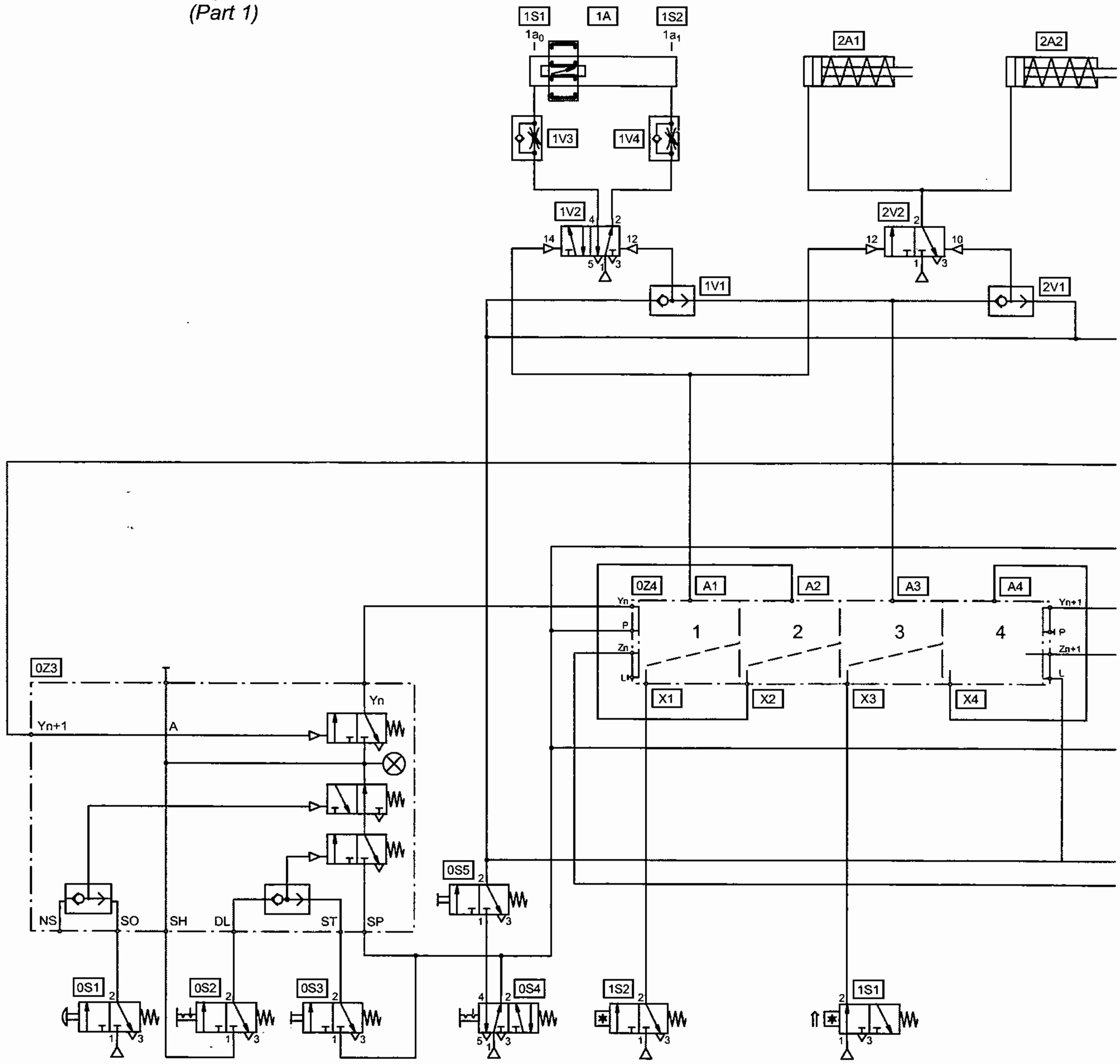
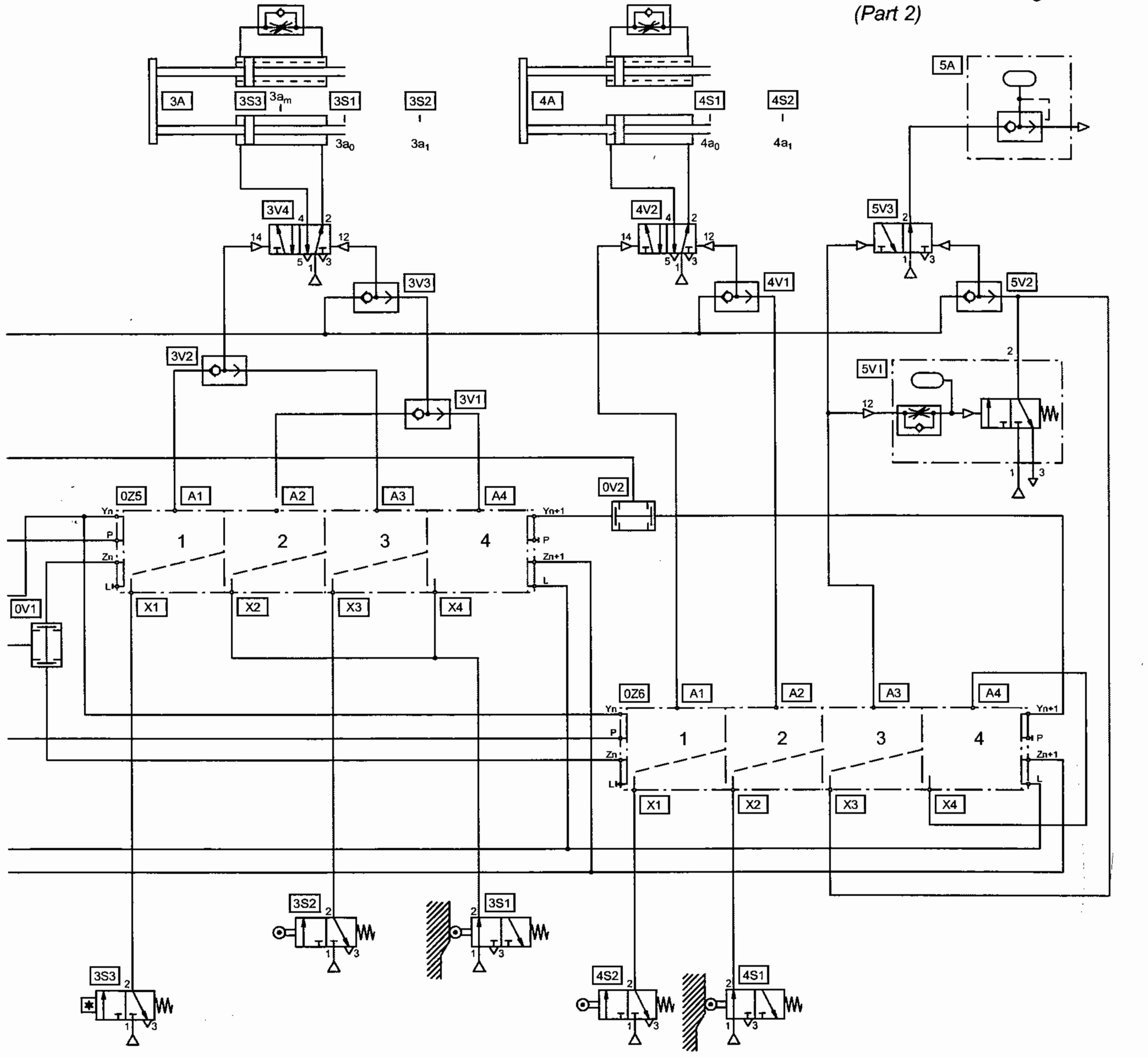


Fig. 16/3:
Extended circuit diagram
(Part 2)



Drilling of cast iron frames - Alternative circuits B, C

Notes on procedure

The sequencer (Quickstepper)

We regard the sequencer as a “black box”. Its mechanics are not of interest to us, only its operation and connection are of significance.

Unlike the stepper module, which switches across to the right (X1 to A2, X2 to A3 etc.), the Quickstepper switches through vertically (X1 to A1, X2 to A2 etc.). Bear this in mind, when you need to switch manually or carry out fault finding.

The "OUTPUT" button is located on the control panel of the unit and can only be switched if there is no pressure at the “AUTO” connection; i.e. valve (0S1) must be set to “MAN”. If “OUTPUT” is set to 1, then the preselected step is executed. If this button is set to 0, then the desired step can be selected via “MAN. STEP”. The step to be applied is displayed in the counter window (step display). Two small signal indicating pins “P” (white) and “INPUT” (blue) indicate whether pressure is available at the output in question or whether a step has been executed. In the initial position, the Quickstepper displays the figure 12 in the counter window.

Other equipment

Feed unit (1A) with hydraulic cushioning cylinder is simulated by means of a single-acting cylinder. This must, however, be throttled as otherwise the program cycle would be executed far too quickly and it would therefore be hardly possible to register, follow and check the individual steps.

The pneumatic counter (0V2) cannot be reset pneumatically in this circuit and must be reset manually. If it is set to "0", without this being noticed, you may find yourself looking for faults which do not exist.

It is a START condition that the actuators and processors are in their initial positions. Actuator (1A) is retracted, actuators (2A) and (3A) are extended. By connecting an additional piece of tubing to port "L" of the Quicksteppers, the latter can be set. The reset process can be carried out by means of manual switching from step to step. This process is also a function check for the signalling elements.

Check each signalling element for correct switching and label each valve immediately (soft pencil, self-adhesive labels).

Components list

Components	*Quantity*	*Designation*
1A	1	Single-acting cylinder
2A, 3A	2	Double-acting cylinder
1V7, 2V1, 3V1	3	5/2-way double pilot valve
1V1, 1V2, 1V3, 1V4, 1V5, 1V6	2	Shuttle valve, 3-fold
0Z4	1	Sequencer
0V3	1	Dual-pressure valve
1S1, 1S2, 2S1	3	3/2-way roller lever valve, normally closed
3S1, 3S2	2	Pneumatic proximity switch
2S2	1	Back pressure valve
0V1	1	3/2-way pneumatic valve, convertible
0V2	1	Pneumatic preselect counter
0Z3	1	Visual indicator
0S1	1	3/2-way valve with selector switch, normally closed
0S2	1	3/2-way valve with push button, normally closed
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	20	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 17/2:
Circuit diagram

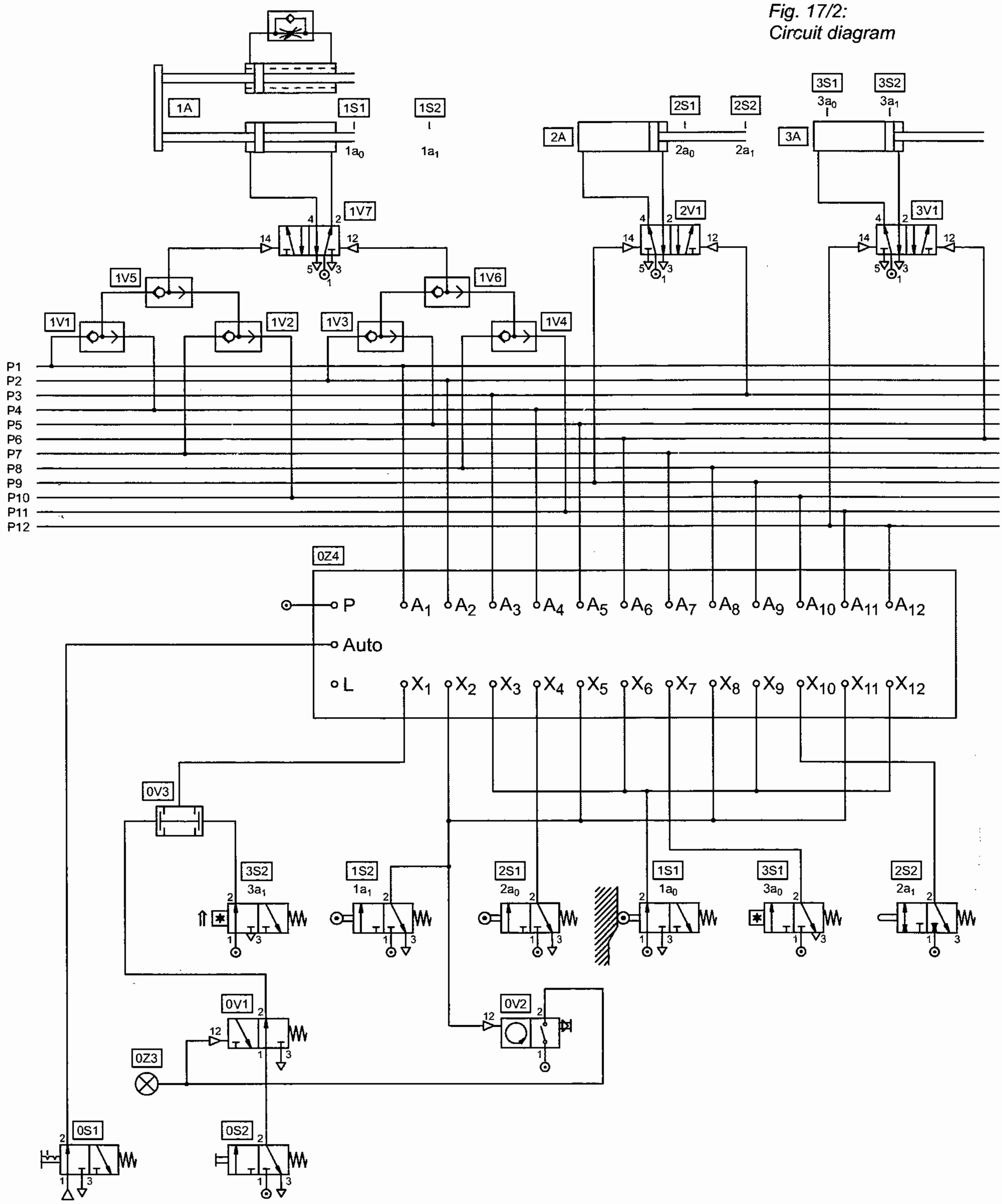
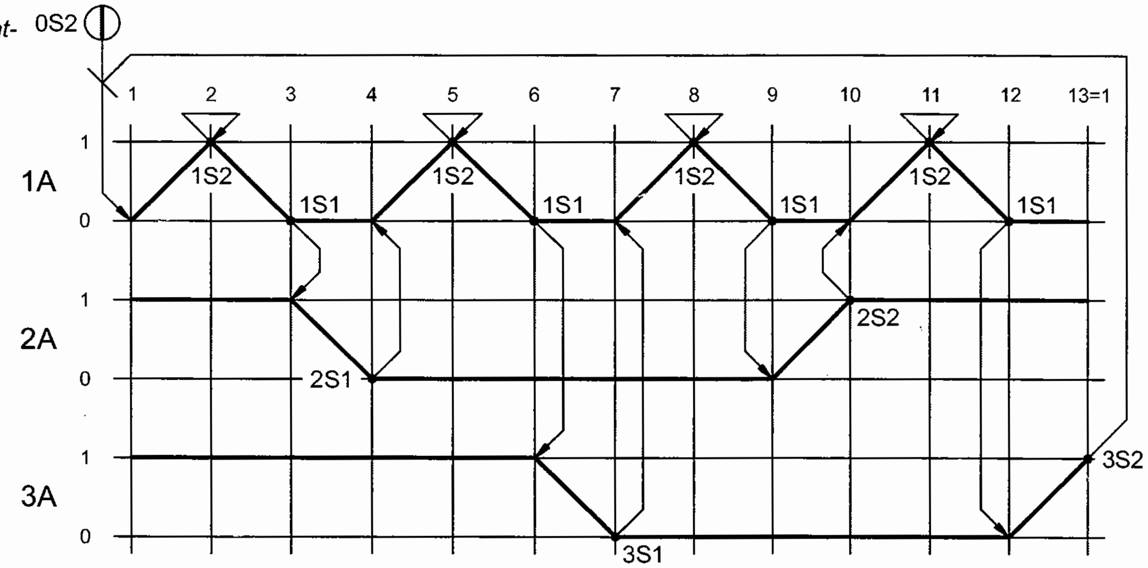


Fig. 17/3:
Displacement-
stepdiagram



Solution description

Initial position

Cylinder (1A) is in its retracted end position, cylinders (2A) and (3A) in their forward end position.
Sensors (1S1), (3S2) and (2S2) are actuated. The pneumatic preselect counter is set to 80 (8) drilling operations. The 3/2-way pneumatic valve (0V1) is normally open. The 3/2-way valve with selector switch (0S1) is set to 'Automatic'. The sequencer (0Z4) (Quickstepper) is in the 12th step. The "OUTPUT" switch is located in position 1 (righthand switching position).

Step 1-2 – Drilling cylinder (1A) extends (1A+).

If the START signal and the signal of the pneumatic proximity switch (3S2) are applied to the dual-pressure valve (0V3), port X1 of the Quickstepper (0Z4) is pressurised. Output signal A1 reverses the final control element (1V7) via shuttle valves (1V1) and (1V5) and line P1. The feed unit (1A) advances. In its forward end position, cylinder (1A) actuates roller lever valve (1S2). As a result, a step is subtracted at the preselect counter (0V4) and port X2 of the Quickstepper is pressurised.

Step 2-3 – Drilling cylinder (1A) retracts (1A-).

Output signal A2 reverses final control element (1V7) via P2 and valves (1V3) and (1V6). The drilling unit retracts. The roller lever valve (1S1) is actuated and as a result connection X3 pressurised.

Step 3-4 – Transfer cylinder (2A) retracts (2A-).

Output signal A3 reverses the final control element (2V1). Cylinder (2A) retracts and actuates the roller lever valve (2S1). Connection X4 of the Quickstepper is supplied with air.

Step 4-5 and 5-6 –
Drilling cylinder (1A) advances and retracts (1A+), (1A-).

Output signal A4 reverses the final control element (1V7) via line P4 and (1V1) and (1V5). Cylinder (1A) advances. In its forward end position, it actuates valve (1S2) once again. A further counting pulse subtracts one step at the preselect counter. Port X5 is pressurised. Signal A5 returns cylinder (1A) back to its retracted end position. There it actuates roller lever valve (1S1). Port X6 is supplied with air.

Step 6-7 – Transfer cylinder (3A) retracts (3A-).

Output signal A6 reverses the final control element (3V1). Cylinder (3A) retracts and actuates the pneumatic proximity switch (3S1). Port X7 of the Quickstepper is supplied with air.

Steps 7-8 to 12-13 proceed as described above.

If cylinder (3A) has extended, it actuates the pneumatic proximity switch (3S2). Its continuos signal is once again present at the dual-pressure valve (0V3). A renewed START signal can start the next cycle.

Marginal conditions

- **Stop for drill change**
  If the pneumatic preselect counter has subtracted the permitted number of holes (indication of tool life), the resulting output signal switches the 3/2-way pneumatic valve (0V1) to the normally closed position. The START signal is thus blocked. If the preselect counter is reset manually after the drill change, valve (0V1) switches back to the normally open position. Now it is possible to make a renewed start.

- **Changeover to manual step mode**
  If the 3/2-way pneumatic valve (0S1) is set to MANUAL, the AUTO connection on the Quickstepper (0Z4) is exhausted. It can then be advanced manually using the MAN. STEP key. The actuators only execute the movement specified in the current step. When outputs are switched off (OUTPUT switch set to 0) a required step can be selected using the MAN.STEP key. By moving the OUTPUT switch to position 1, the appropriate output is connected and the command thus executed.

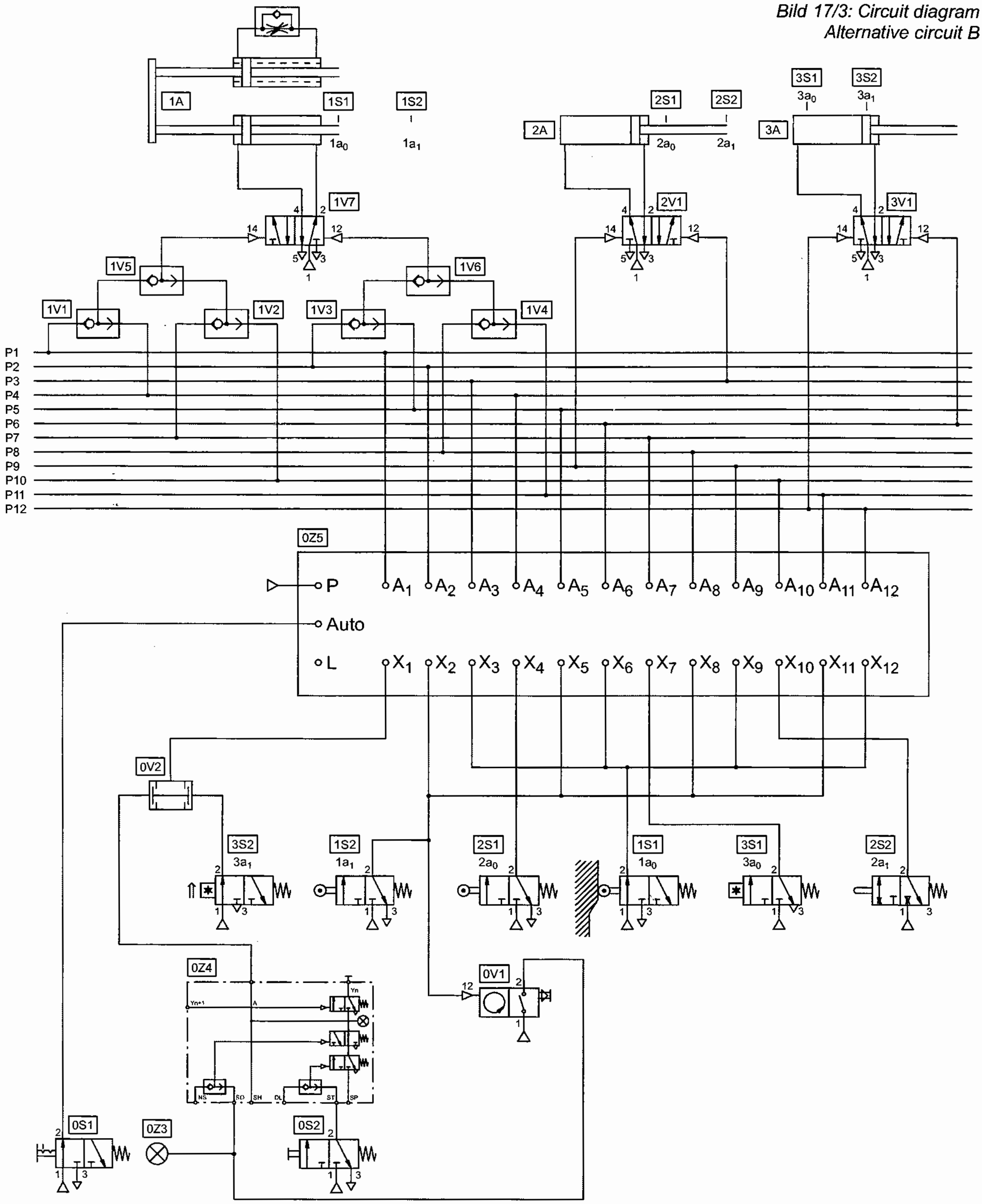
Further development

As has already been explained, each cycle must be restarted manually via valve (0S2), the START button. The counter (0V2) ensures that the tool life is not exceeded. It is conceivable that even the insertion of parts could be automated. In that case, manual start would no longer be suitable.

This extension of the marginal conditions has been thought out in advance and systematically incorporated in the memory module. The memory module is not a component in the equipment set, but an additional component.

- Replace the 3/2-way pneumatic valve (0V1) with the command module (**alternative circuit B** on the next page). Plug ports "SH" and "Yn" of the memory module. The controller also has only the AUTOMATIC/MANUAL and START functions. What advantages/disadvantages result from the use of the memory module?
- In addition, realise the functions CONTINUOUS CYCLE/SINGLE CYCLE and STOP at END OF CYCLE (**alternative circuit C** on the page after next). Label the functions. What additional ease of operation is provided by the functions MAN.STEP (manual stepping) and OUTPUT of the Quicksteppers compared to the sequencer? Test all combinations! Is intentional of inadvertant maloperation possible?
- Construct the control system using three stepper modules.

Bild 17/3: Circuit diagram
Alternative circuit B



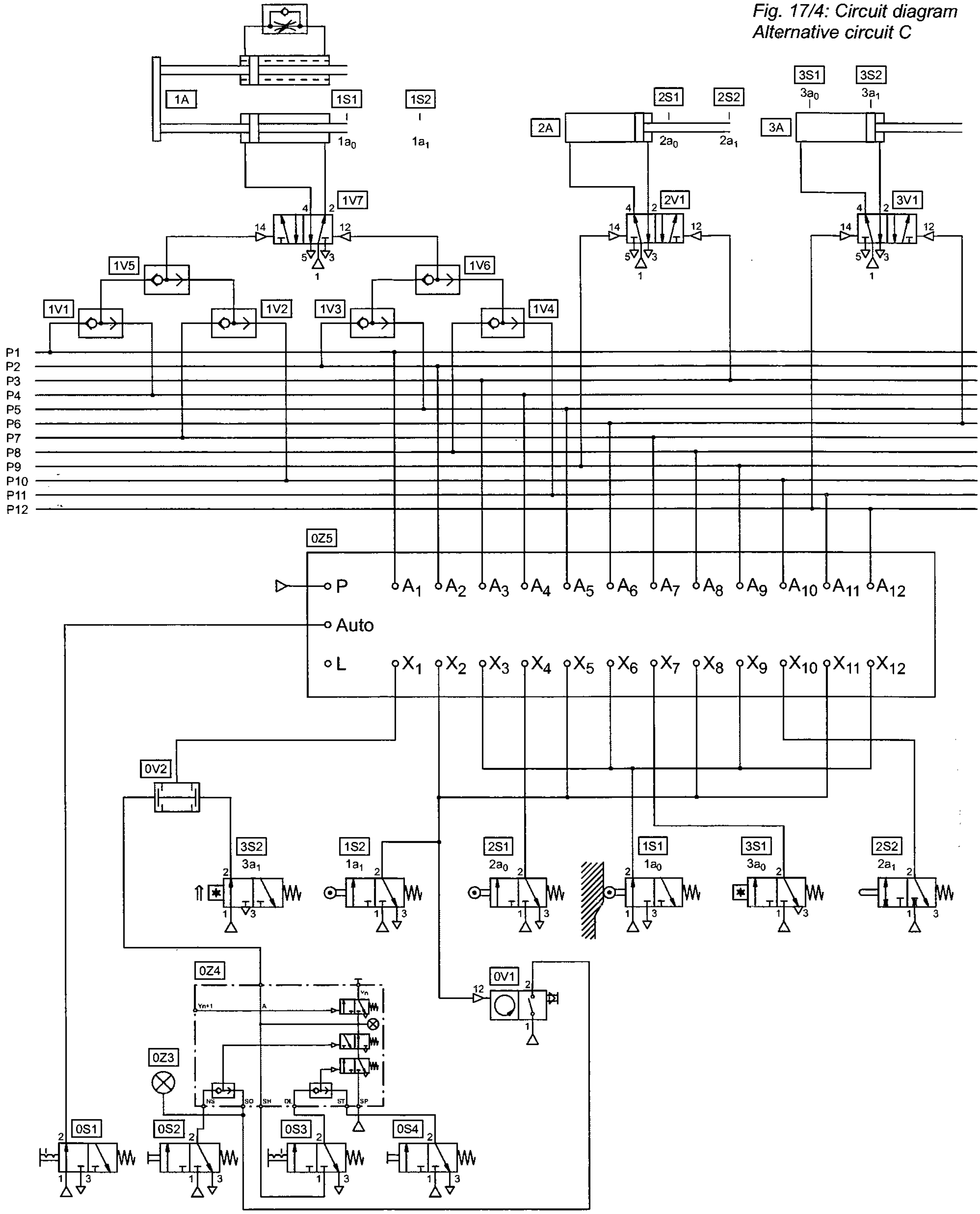


Fig. 17/4: Circuit diagram
Alternative circuit C

Turning unit for sand blasting

Notes on procedure

The individual components

As shown in previous exercises, components have to be simulated or else directional control valves are converted.

Since this exercise is very extensive, certain valves and quick push-pull distributors must be used which are not included in the equipment sets TP101 and TP102 (see components list).

The reversing actuator (4A) is to be replaced by the pneumatic linear drive, which is equipped with two one-way flow control valves. Directional control valves (2V4), (5V1) and (0V1) are to be converted into 3/2-way valves (plug port 2).

Component (2V3) is a time-delay valve with which the time for sandblasting is to be determined. On the sequencer (Quickstepper) (0Z5) use the "MAN.STEP" and "OUTPUT" keys to select whether you wish to "set", "test step by step" or whether you wish to run through the entire cycle. The back pressure nozzle (2S2) requires the usual fine adjustment (adjusting to the cylinder).

The memory module (0Z3) coordinates the circuit for the "marginal conditions". Sequencer (0Z5) is activated by valve (0S1) in such a way that the automatic execution of the step sequence can be interrupted. Push-button valve (0S3) interrupts the self-latching circuit in the command module (0Z3) so that the system comes to a standstill at the end of the cycle. The latching cycle switch (0S4) can either create this self-latching circuit (CONTINUOUS CYCLE) or break it (SINGLE CYCLE). The START pulse to set up a self-holding circuit is given via (0S5).

Program selection is made via the program switch (0S6). The complete program I is achieved in conjunction with AND valves (0V11), (0V12) and (0V13). Subprogram II is suppressed in sections by (0V13), (0V11) and (0V12). OR valves (0V7), (0V8), and (0V9) are required to bridge the signals no longer included. Since only 11 steps are required, signal A11 is transmitted to X12.

Possible problems

- The signal elements only switch correctly when they have been adjusted. The sensors should be checked to determine whether the signals are transmitted and whether they arrive at the sequencer (Quickstepper).

  Checking procedure

1S1 and 3S1	at X11
1S2	at X2
2S1	at X5 and X10
2S2	at X4 and X9
3S1	at X6 and together with $1a_0$ (1S1) at X11
3S2	at X8 and together with the adjustable vacuum actuator (0V2)
4S1	and not adjustable vacuum actuator(0V2) and A12 via memory module at X1
4S2	at X7

  If a signal does not arrive, the sequencer remains in the step in question. This step can be read from the Quickstepper or the displacement-step diagram.

  Suction cup (5A) must be aligned to ensure it operates correctly and and so that this signal is not omitted. The roller lever valve (0S1) must be continuously actuated - full magazine - otherwise the system will stop at the end of the cycle. Simulate this with a normally 3/2-way valve.

- Final control elements are incorrectly actuated. Components (1V1), (3V3) and (4V1) should not present any problems; however (2V4) and (5V1) will need to be correctly converted.

Marginal conditions

If these inputs do not take place, it may mean that the system is not starting up properly, which is why valves (0S2) to (0S6) must be defined and adjusted correctly.

MAN/AUTO

3/2-way ventil with selector switch (0S2)

- MANUAL position:
  No pressure at the AUTO connection of the Quickstepper. The controller can only be advanced step-by-step by pressing the MAN.STEP key after every step.
- AUTOMATIC position:
  The cycle runs through automatically.

STOP at END OF CYCLE

3/2-way valve with push button (0S3)

- The installation comes to a standstill at the end of a cycle.
  This does not correspond to EMERGENCY-STOP procedure.

CONTINUOUS CYCLE/SINGLE CYCLE

3/2-way valve with selector switch (0S4)

- CONTINUOUS CYCLE position:
  The self-latching circuit in the memory module (0Z3) is generated via connections "SH" and valve (0S4) "DL" - i.e. pressure after (0S4).
- SINGLE CYCLE position: Interruption of the self-latching circuit so that input X1 can be triggered only once via START (0S5) and (0V6), i.e. there is no signal at connection "DL" of the memory module.

START

3/2-way valve with push button (0S5)

Program I/II

5/2-way valve with selector switch (0S6)

- Program I:
  Continuous signal at dual-pressure valves (0V11), (0V12) and (0V13)
- Program II:
  Continuous signal at shuttle valves (0V7), (0V8) and (0V9)

Components list

Components	Quantity	Designation
1A, 3A	2	Double-acting cylinder
2A	1	Single-acting cylinder
4A	1	Linear drive, pneumatic
5A	1	Vacuum generator/suction cup
0V1, 0V3	2	3/2-way pneumatic valve, convertible
0V5, 0V6, 0V10, 0V11, 0V12, 0V13	2	Dual-pressure valve, 3-fold
0V4	1	Dual-pressure valve
0V7, 0V8, 0V9, 2V2, 3V1, 3V2	2	Shuttle valve, 3-fold
2V1	1	Shuttle valve
1V2, 1V3, 3V4, 3V5	4	One-way flow control valve
1V1, 2V4, 3V3, 4V1, 5V1	5	5/2-way double pilot valve
0S1	1	3/2-way valve with pushbutton, normally open
0S2	1	3/2-way valve with selector switch, normally closed
0S3, 0S5	2	3/2-way valve with detent switch, normally closed
0S4	1	3/2-way valve with mushroom actuator, red, norm. closed
0S6	1	5/2-way valve with selector switch
1S1, 1S2, 2S1, 3S2	4	3/2-way roller lever valve, normally closed
2S2	1	Back pressure valve
3S1, 4S1, 4S2	3	Pneumatic proximity switch
0V2	1	Adjustable vacuum actuator
2V3	1	Time delay valve, normally closed
0Z5	1	Sequencer
0Z4	1	Visual indicator
0Z3	1	Memory module
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	17	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

In the circuit diagram, (Fig. 18/2) component (0S1) is shown as a roller lever valve. This roller lever valve for magazine sensing must be continuously actuated or else the controller will come to standstill at the end of the cycle. For simulation purposes, a 3/2-way valve with push button, normally open, can be used.

Fig. 18/2:
Circuit diagram

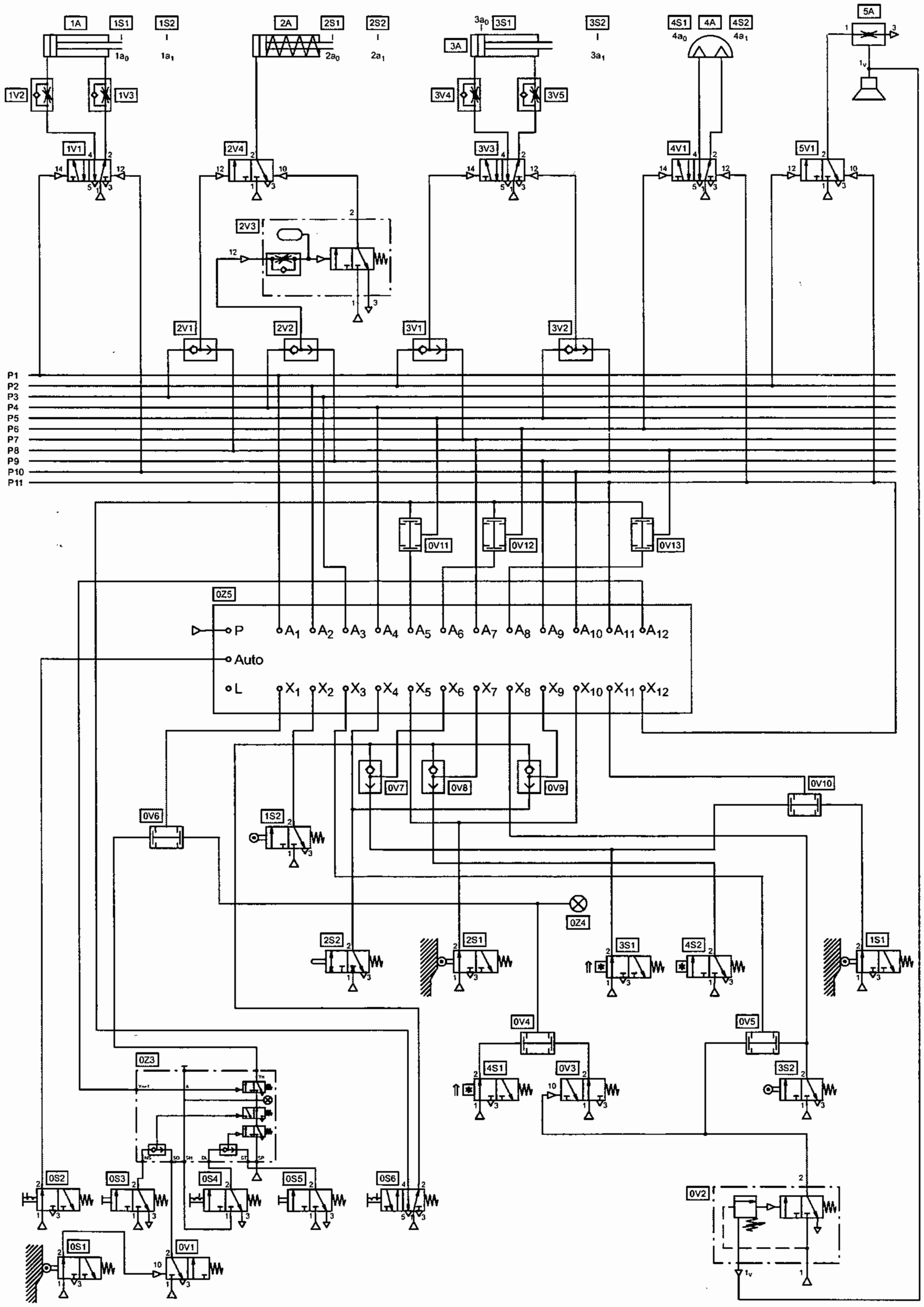
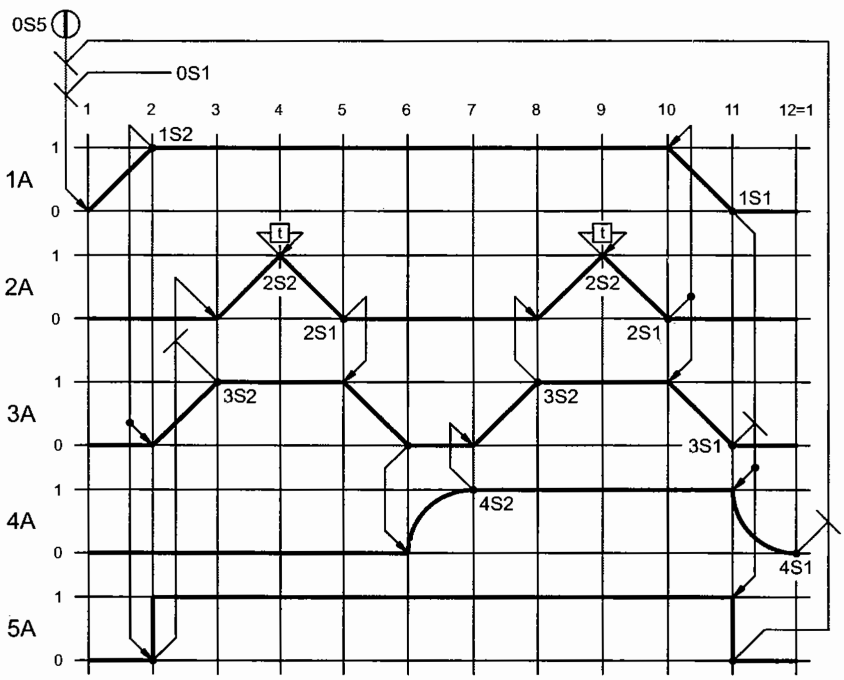


Fig. 18/3:
Displacement-step
diagram
(Program I)



Solution description

Initial position

Actuators (1A) to (3A) are located in their retracted end positions. The vacuum generator (5A) is switched off. The sequencer (0Z5) is located in step 12. The OUTPUT switch is located in position 1.

Sensors (1S1), (2S1), (3S1) and (4S1) are actuated. The magazine sensor valve (0S1) is actuated. Switching valve (0S2) is switched to AUTOMATIC, flow from 1-2, valve (0S4) to CONTINUOUS CYCLE, flow from 1-2, and valve (0S6) to program I, flow from 1-2.

1. Continuous cycle: - Program I

Step 1-2 – Separating cylinder (1A) advances (1A+).

Via the START signal (0S5), the signal from the actuated proximity sensor (4S1) and the signal from the unactuated pneumatic valve (0V3), the dual-pressure valve (0V6) is supplied with air on both sides. Final control element (1V1) is reversed via connections X1 - A1 of the sequencer (0Z5). Cylinder (1A) advances. This actuates the roller lever valve (1S2). Connection X2 of the sequencer is supplied with air.

Step 2-3
Transfer cylinder (3A) advances.
Vacuum generator activated (3A+, 5A+).

The signal from output A2 reverses final control elements (3V3) and (5V1). This causes cylinder (3A) to advance and actuates the roller lever valve (3S2). The vacuum generator is also switched on. The vacuum generated reverses the adjustable vacuum actuator (0V2). Two signals are now present at the dual-pressure valve (0V5). Connection X3 is supplied with air.

Step 3-4 – Valve cylinder (2A) extends (2A+).

The signal from output A3 reverses the final control element (2V4). Cylinder (2A) extends and actuates the back pressure valve (2S2). Connection X4 is supplied with air.

Step 4-5 – Valve operating cylinder (2A) retracts (2A-).

Output signal A4 supplies time delay valve (2V3) with air. After the set time of t = 2 sec, the final control element (2V4) is reversed. Cylinder (2A) retracts and actuates the roller lever valve (2S1). A signal is applied to connection X5.

Step 5-6 – Transfer cylinder (3A) retracts (3A-).

Output signal A5 reverses the final control element (3V3). Cylinder (3A) retracts and actuates the proximity sensor (3S1). A signal is applied at connection X6.

Step 6-7
Reversing actuator (4A) turns the workpiece (4A+), realised through the pneumatic linear drive.

Signal output A6 reverses the final control element (4V1). The linear drive travels to the right and actuates the proximity switch (4S2). Connection X7 is supplied with air.

Step 7-8 – Transfer cylinder (3A) extends (3A+).

Output signal A7 reverses the final control element (3V3). Cylinder (3A) extends and actuates the roller lever valve (3S2). Its signal supplies connection X8 with air (connection X3 is also supplied with air but, since the sequencer is located in step 7, output A3 is blocked).

Step 8-9 – Valve cylinder (2A) extends (2A+).

Output signal A8 reverses the final control element (2V4). Cylinder (2A) extends and actuates the back pressure valve (2S2). Its signal is applied to connection X9.

Step 9-10 – Valve cylinder (2A) retracts (2A-).

Output signal A9 reverses the final control element (2V4) via the time delay valve (2V3). Cylinder (2A) retracts and actuates the roller lever valve (2S1). Its signal pressurises connection X10.

Step 10-11
Transfer cylinder (3A) and separating cylinder (1A) retract (3A-, 1A-).

Output signal A10 reverses the two final control elements (1V1) and (3V3) via line P10. Cylinders (3A) and (1A) retract and actuate the proximity switch (3S1) and the roller lever valve (1S1). If both movements have been acknowledged, a signal is supplied at connection 11.

Step 11-12
Reversing actuator (4A) turns back, vacuum generator switches off (4A-, 5A-).

Output signal A11 reverses the two final control elements (4V1) and (5V1) via line P11 and supplies connection X12 with air. The linear drive travels to the left and the vacuum generator is switched off. The signals of the unactuated pneumatic valve (0V3) and the proximity switch (4S1) are applied to the dual-pressure valve (0V4). Visual indicator (0Z4) is illuminated and a signal is applied to the dual-pressure valve (0V6). Output signal A12 reverses a 3/2-way valve in the memory module (0Z3). As the self-latching circuit is still maintained, a new cycle is started up via the dual-pressure valve (0V6) with no additional START signal.

When the controller is located in the initial position and the 5/2-way valve (0S6) is set to program II (output 4^2 pressurised, START button actuated), then program II is executed.
From step 5-6 onwards, output signals A5, A6 and A8 are suppressed (only one signal at the dual-pressure valve). The sequencer is advanced by means of continuous signals to connections X6, X7 and X9, whereby signals X5 and X10 are emitted by the roller lever valve (2S1).

2. CONTINUOUS CYCLE - Program II

By unlatching valve (0S4), the self-latching circuit in the memory module (0Z3) is interrupted. Thus, continuous signal A12 remains ineffective.

3. SINGLE CYCLE

STOP at END OF CYCLE
The self-latching circuit in the memory module (0Z3) interrupted by actuation of the 3/2-way valve (0S3). If the magazine control valve (0S1) is no longer actuated, pneumatic valve (0V1) reverses and, likewise breaks the self-latching circuit.

4. Marginal conditions

When valve (0S2) is switched to manual operation, the sequencer can be advanced by hand.

Setting mode

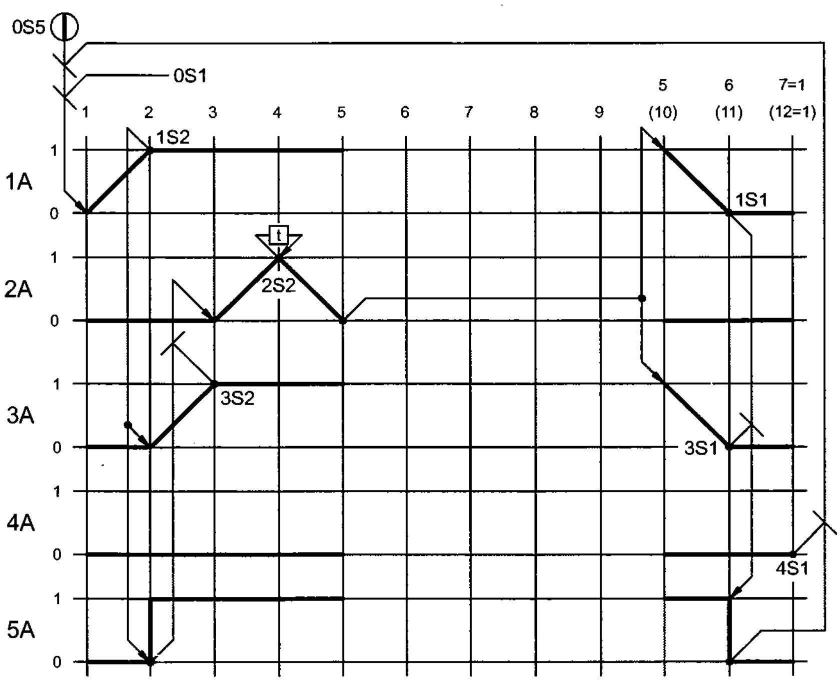


Fig. 18/4: Displacement-step diagram (Program II)

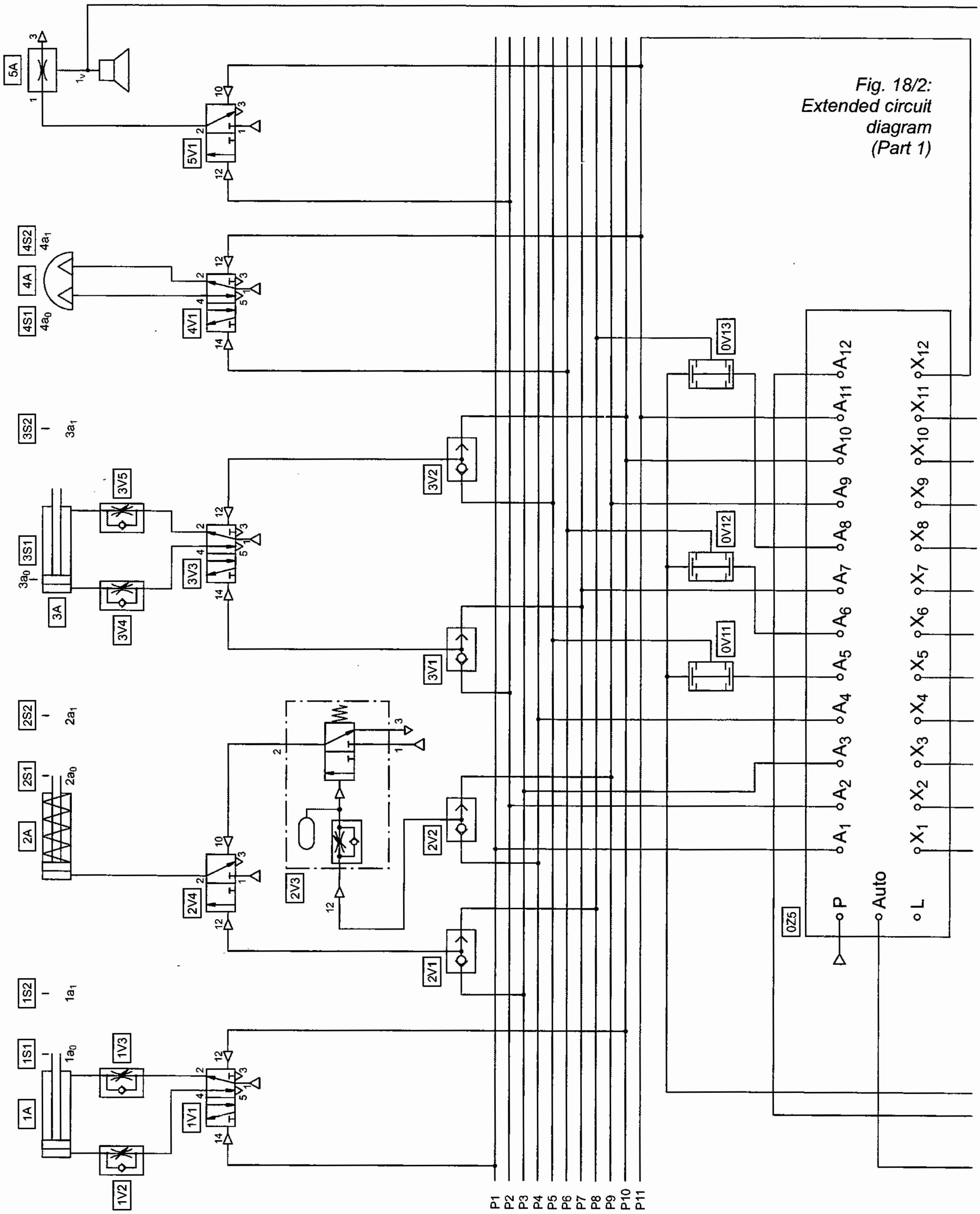
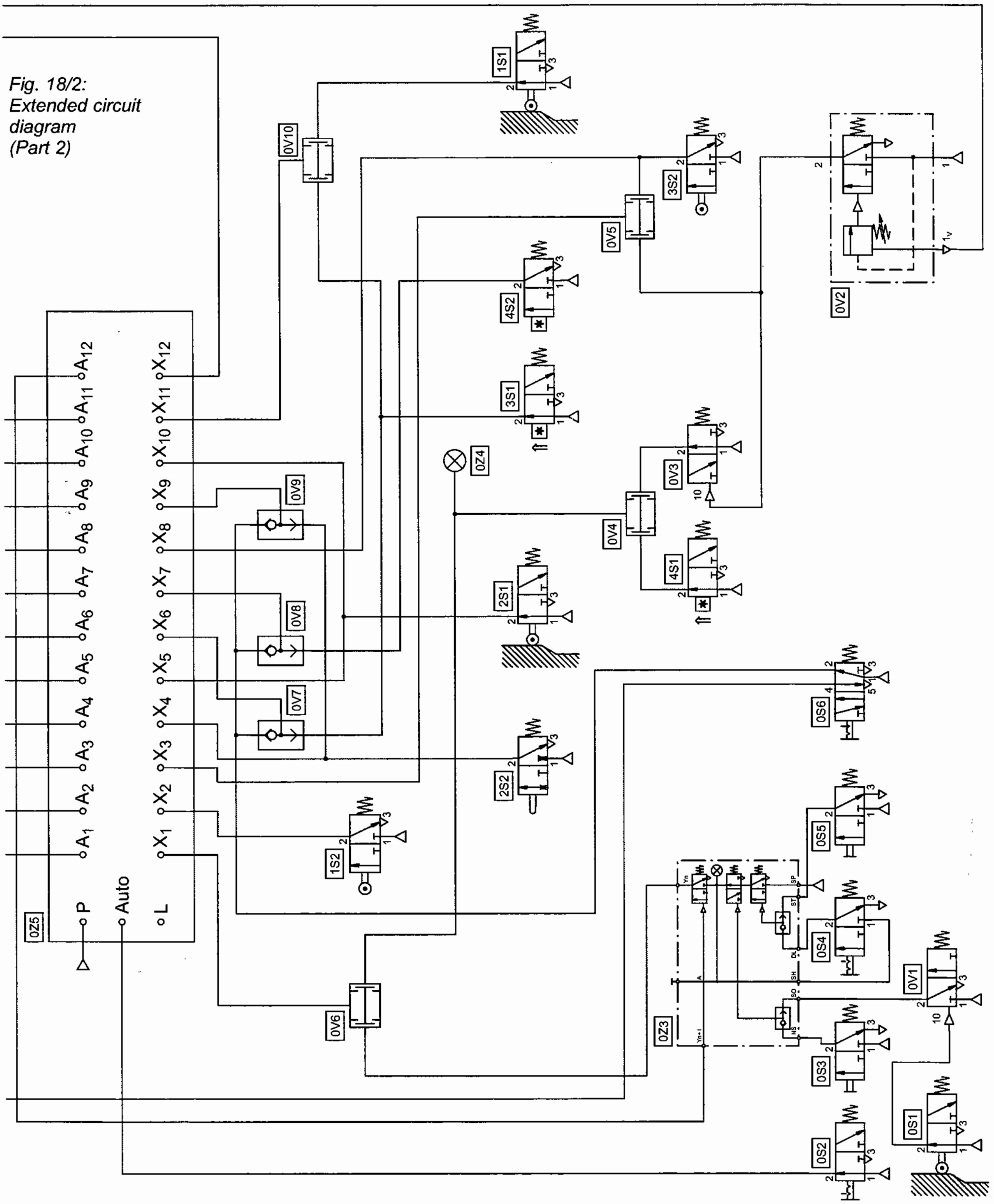


Fig. 18/2:
Extended circuit
diagram
(Part 1)

Fig. 18/2:
Extended circuit
diagram
(Part 2)



Pneumatic binary adder

Notes on procedure

Unlike the previous exercises, which all represented some form of work cycle such as "clamping", "bending", "transferring" "rearranging", etc., a counting operation is being performed here. However primitive it may appear to go to such length to "add one plus one", we should like to remind you that the very first version of a "pocket calculator" was the size of a wardrobe and operated with power relays weighing several kilograms. Nowadays, calculators can be integrated into a wristwatch.

Binary numbers

This exercise also acts as an introduction to logic or Boolean algebra. The decimal system can only be realised by means of complicated arithmetic units. It is much simpler to work with the binary system.

To give an example:
The figure 4711 is familiar to us and is generally handled correctly. As a result we tend to forget how it is made up.
4711 is composed of 4 x 1000 + 7 x 100 + 1 x 10 + 1 x 1 or even $4 \times 10^3 + 7 \times 10^2 + 1 \times 10^1 + 1 \times 10^0$.
Binary figures are based on the power of two, which has the advantage that they are well suited to control applications. There are only two different figures, just as there are two different statuses, i.e. pressure and no pressure, flow and no flow.
Example:
The binary figure 10011 corresponds to: $1 \times 2^4 + 0 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$ or 1 x 16 + 0 x 8 + 0 x 4 + 1 x 2 + 1 x 1 or the decimal figure 16 + 2 + 1 = 19.

Development of the circuit

It is possible to think of the three cylinders as holes in a three-track punched tape, representing the values 2^0, 2^1 and 2^2. To solve this problem, start by drawing up a truth table, then add the mathematical solution (equations), followed by a logic diagram, which is realised purely pneumatically using dual-pressure valves, shuttle valves and 3/2-way valves.

Components

The OR gates present problems, because they are INCLUSIVE-OR gates, ie. there is flow when they are pressurised from the right or the left or from both sides.
The combinations of valves (0V3) + (0V4) + (0V7) as well as (0V5) + (0V6) + (0V8) and (0V9) + (0V10) + (0V12) create an EXCLUSIVE-OR, which means there is no longer any flow when they are pressurised from both sides.

Pressure

The pressure regulator (0V14) is to be set so that the final control elements are always moved into the righthand switching position when a signal is received from the left.

Do not disassemble the processor (adder), you will need it again for exercise 20

Components list

Components	*Quantity*	*Designation*
1A	1	Single-acting cylinder
2A, 3A	2	Double-acting cylinder
1V1, 2V1, 3V1	3	5/2-way double pilot valve
0V7, 0V8, 0V12	3	5/2-way pneumatic valve
0V1, 0V2, 0V3, 0V6, 0V9, 0V11	2	Dual-pressure valve, 3-fold
0V4, 0V6, 0V10, 0V13	2	Shuttle valve, 3-fold
0S1, 0S2, 0S3, 0S4	4	3/2-way valve with push button, normally closed
0V14	1	Pressure regulator with pressure gauge
0Z3	1	Processor binary adder
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	20	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Truth table

Input key				*Indicator cylinder (result)*			
1. Addend		2. Addend		binary			decimal
A2	A1	B2	B1	C3	C2	C1	
2^1	2^0	2^1	2^0	2^2	2^1	2^0	
0	0	0	0	0	0	0	0
0	0	0	1	0	0	1	1
0	0	1	0	0	1	0	2
0	0	1	1	0	1	1	3
0	1	0	0	0	0	1	1
0	1	0	1	0	1	0	2
0	1	1	0	0	1	1	3
0	1	1	1	1	0	0	4
1	0	0	0	0	1	0	2
1	0	0	1	0	1	1	3
1	0	1	0	1	0	0	4
1	0	1	1	1	0	1	5
1	1	0	0	0	1	1	3
1	1	0	1	1	0	0	4
1	1	1	0	1	0	1	5
1	1	1	1	1	1	0	6
Allocation not possible				(1)	(1)	(1)	(7)

Equations

C1 = A1 ∆ B1

C2 = (A1 ^ B1) ∆ (A2 ∆ B2)

C3 = (A2 ^ B2) v ((A2 ∆ B2) ^ (A1 ^ B1))

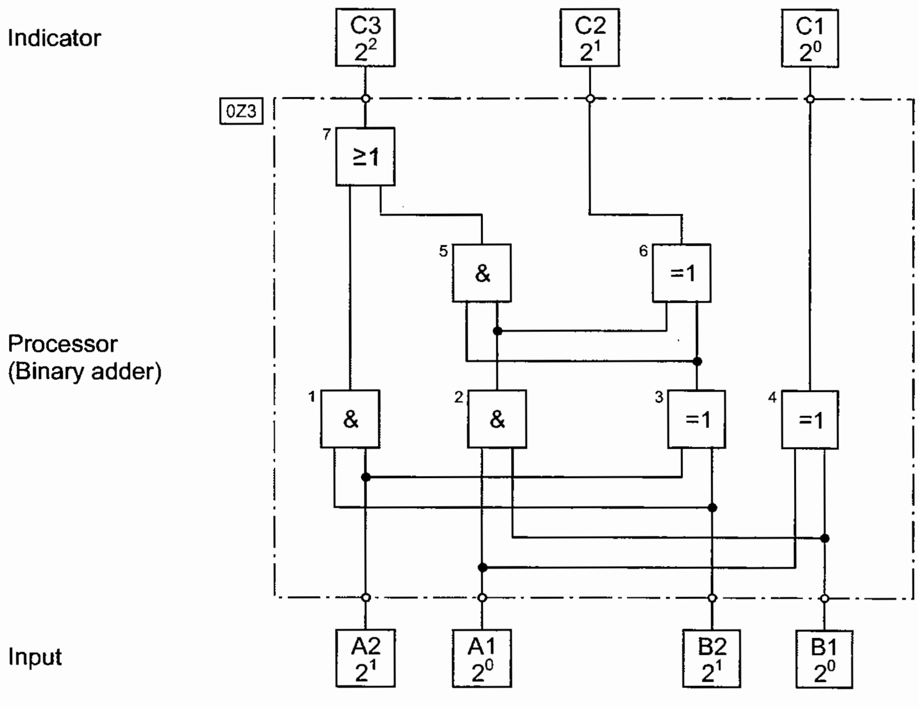
Operands

^ AND

v OR (inclusive)

∆ EXCLUSIVE-OR

Fig. 19/4:
Logic diagram



Note regarding the logic diagram

Figures 1-7 for logic functions (AND, OR as well as EXCLUSIVE-OR) in the processor (0Z3) can be assigned to the operands for the equation (C1=, C2= and C3=).

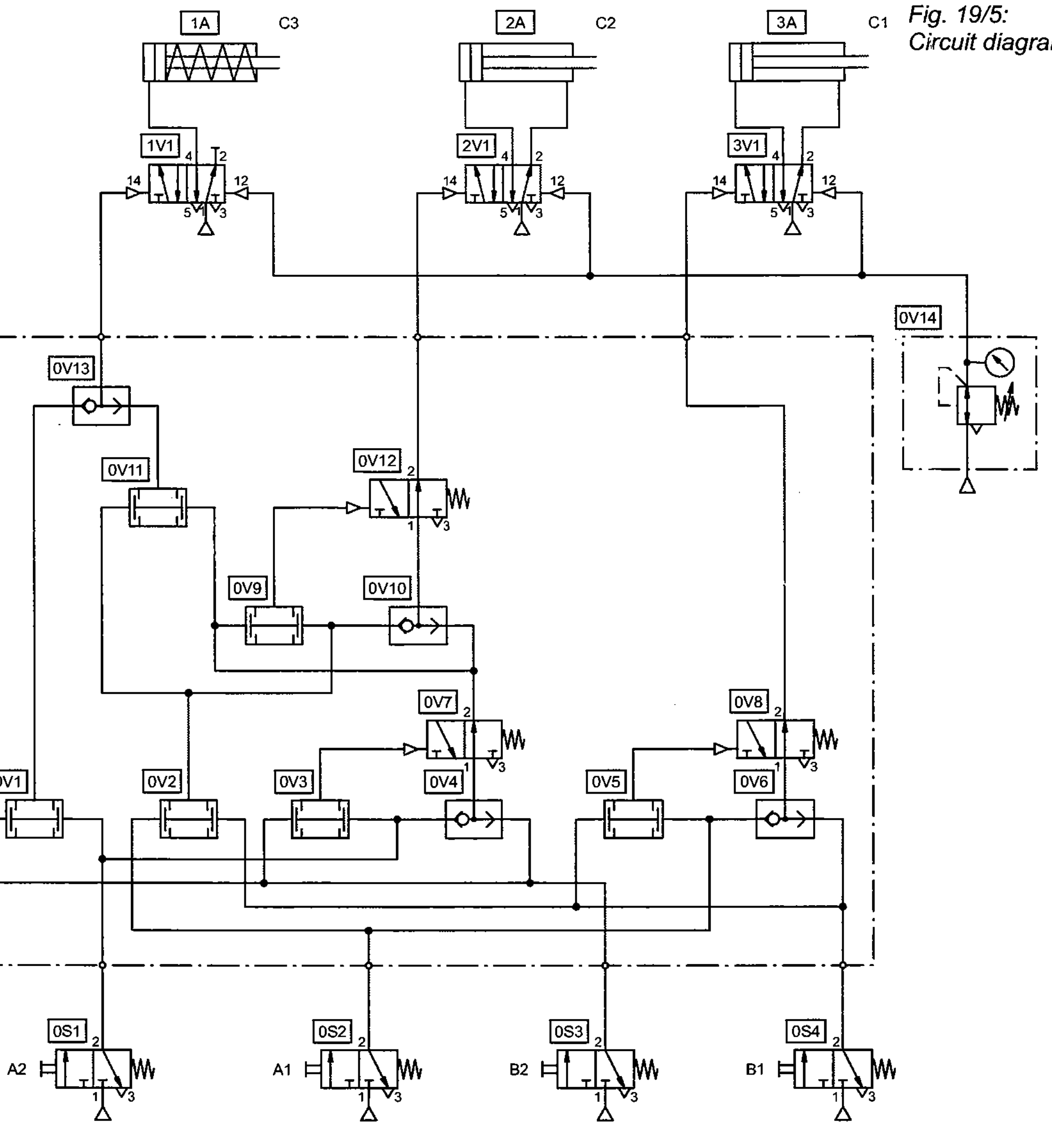


Fig. 19/5:
Circuit diagram

You can save three AND elements in the processor 0Z3, by doing without the explicit presentation of EXCLUSIVE-OR.
The following elements can be assembled together:

Elements 0V1 and 0V3,
elements 0V2 and 0V5 as well as
elements 0V9 and 0V11.

Solution description

Initial position

The three actuators are located in their retracted end positions. Final control elements (1V1), (2V1) and (3V1) are pressurised with a pressure of p = 2.5 bar (250 kPa) by the pressure regulator (0V14) via port 12. The air supply to valves (0S1) to (0S4) is set to a pressure of p = 5 bar (500 kPa).

Input of value 1 via valves A1 (0S2) or B1 (0S4)

Indicator cylinder C1 (3A) extends.
The signal of the 3/2-way valve (0S2) or (0S4) flows through the shuttle valve (0V6), the 3/2-way pneumatic valve (0V8) and pressurises control port 14 of the final control element (3V1). Since a higher pressure is applied at port 14 than at port 12, the final control element is able to reverse. The cylinder (3A) extends. If both push buttons (0S2) and (0S4) are actuated, cylinder (3A) does not extend since the valve (0V8) assumes normally closed position.

Input of figure 2 via valve A2 (0S1) or valve B2 (0S3)

Indicator cylinder C2 (2A) extends.
If input valve A2 (0S1) is actuated then the control air pressurises port 14 of the final control element (2V1) via the shuttle valve (0V4), the 3/2-way pneumatic valve (0V7), the shuttle valve (0V10) and the 3/2-way pneumatic valve (0V12). Cylinder (2A) extends. Correspondingly, B2 (0S3) is actuated via valves (0V4), (0V7), (0V10) and (0V12).

Input of figure 1 via valve A1 (0S2) and valve B1 (0S4)

Indicator cylinder C2 (2A) extends.
If the two valves (0S2) and (0S4) are actuated simultaneously, the dual-pressure valve (0V2) has through flow. The pilot air pressurises port 14 of the final control element (2V1) via the shuttle valve (0V10) and the 3/2-way pneumatic valve (0V12). Cyiinder (2A) extends. The dual-pressure valve (0V5) is also pressurised from two sides and has through flow. Pneumatic valve (0V8) closes off flow to the final control valve (3V1).

Input of value 3 via valve A1 (0S2) and valve B2 (0S3)

Indicator cylinders C1 (3A) and C2 (2A) extend.
If valves (0S2) and (0S3) are actuated simultaneously, (3V1) is pressurised by valve (0S2) via (0V6) and (0V8), whereupon cylinder C1 (3A) extends. At the same time, the signal reaches the final control element (2V1) from (0S3) via (0V4), (0V7), (0V10) and (0V12), and is indicated by C2 (2A).

Further input possibilities

Figure 4: A1 + B1 + A2 or A1 + B1 + B2 or A2 + B2 = C3 (1A) extends.
Figure 5: A2 + B2 + A1 or A2 + B2 + B1 = C1 (3A) and C3 (1A) extend.

The binary adder can perform 15 calculations. The decimal figure 7 (all three actuators extended) cannot be shown.

Pneumatic binay adder with memory

Notes on procedure

Extent of exercise

The circuit for a "binary adder" or a general "processor" was given in exercise 19. The disadvantage was that the result was only displayed whilst the enter key(s) was being pressed.

This deficiency is now corrected in exercise 20, i.e. a "memory" is to be incorporated in the "adder", whereby this is represented by the block (0Z3) of exercise 19. The components between the input function (2^0, 2^1, "plus", "equals", input position "C") and the "adder" represent the "memory". The memory is made up of pilot-operated 3/2- and 5/2-way valves, whereby the relevant valve position represents the "memory". Indication by the cylinders (the result of the addition) takes place when the result is called up via the "equals" function and is maintained until the arithmetic unit is returned to the initial position via valve (C).

Counting mode

The counting mode of the computer is as follows: The first addend formed by push button A2 and A1 and 2^0 and 2^1 without "plus" being pressed. This value is filed in memory 1 and displayed. When "plus" is pressed, the switch is set from memory 1 to memory 2. The second addend can now be input via the same push button. This figure is now filed in memory 2 and displayed.

When "equals" is pressed, the overall result is displayed, i.e. the memory 1 is switched via memory activation 1. Display is effected via the cylinders, which represent the values $2^0 = 1$, $2^1 = 2$ and $2^2 = 4$. Input passes via the push-button valves with the values $2^0 = 1$ and $2^1 = 2$.

Example: 3 + 2 = 5 (Decimal values)

Step 0	"C" - Initial position	
Step 1	Push button 2^0 actuated - cylinder 2^0 extends -decimal value 1	Steps 1 and 2 may take place consecutively or simultaneously
Step 2	Push button 2^1 actuated cylinder 2^1 extends - decimal valve 2	
Step 3	"Plus" actuated - interim sum 1 with decimal value 3 is stored and both cylinders retract in order to assume new values.	
Step 4	Push button 2^1 actuated - cylinder 2^1 extends - decimal value 2	
Step 5	Equals" actuated - interim sum 1 (decimal value 3) and interim sum 2 (decimal value 2) are added, cylinders 2^0 and 2^2 extend.	
Step 6	see step 0	

Components required

A convertible 3/2-way pneumatic valve and two 5/2-way pneumatic valves as well as several quick push-pull distributors are required in addition to the two equipment sets TP101 and TP102.

Identification of components

This exercise is the most extensive and also the most complex of the entire collection of exercises.

Please note:
1. Label all valves to be used immediately.
2. Check converted 3/2-way valves for correct flow.
Example: 3/2-way pneumatic valves for the adder must not have throughflow when there is a signal.

General evaluation

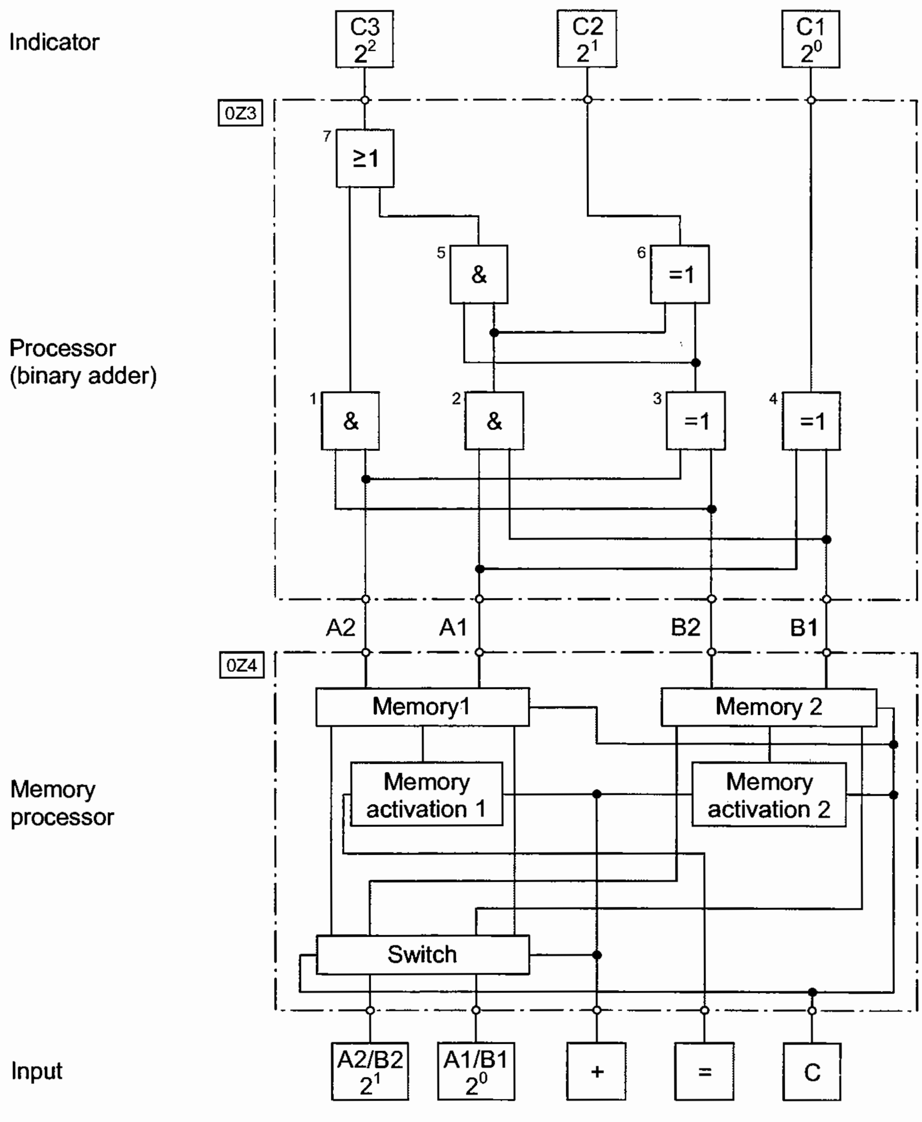
It is certainly surprising to see the extent of the circuit required to count to "6" and how much more extensive and complex would the circuit of a pocket calculator be. (Or: what thought processes are required for this and what circuit possibilities are available from a chip!)

Components list

Components	*Quantity*	*Designation*
1A	1	Single-acting cylinder
2A, 3A	2	Double-acting cylinder
1V1, 2V1, 3V1	3	5/2-way pneumatic valve
0V1, 0V2, 0V3, 0V5, 0V9, 0V11	2	Dual-pressure valve, 3-fold
0V4, 0V6, 0V10, 0V13	2	Shuttle valve, 3-fold
0V7, 0V8, 0V12	3	3/2-way pneumatic valve, convertible
0V14, 0V15, 0V16, 0V17, 0V18, 0V19, 0V20, 0V21	8	5/2-way double pilot valve
0S1, 0S2, 0S3, 0S4, 0S5	5	3/2-way valve with push button in normally closed position
0Z4		Memory processor
0Z3		Processor binary adder
0Z2	1	Manifold
0Z1	1	On-off valve with filter regulator
	37	Push-in T-connector

Components (0Z1) and (0Z2) are not shown in the circuit diagram.

Fig. 20/4:
Block circuit diagram



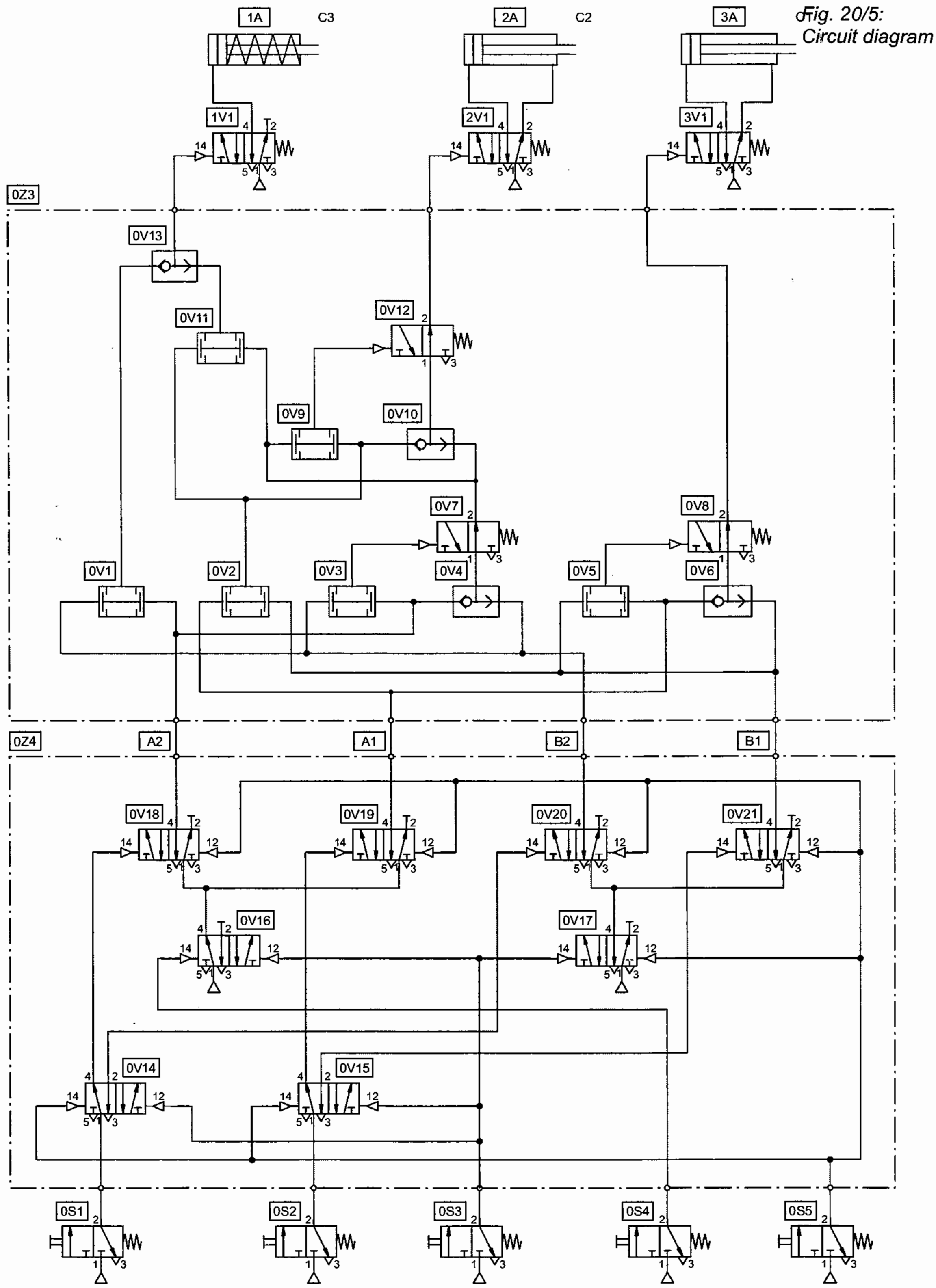


Fig. 20/5:
Circuit diagram

Solution description

Initial position

The three actuators are located in their retracted end positions. Memory valves (0V18); (0V19), (0V20) and (0V21) are closed. Memory activating valve (0V16) has throughflow, activating valve (0V17) is closed. Switches (0V14) and (0V15) assume the righthand switching position. Input valves (0S1) to (0S5) are in the normally closed position.

1. Addition: 1 + 1

Input		*Movement*		*Display value*	
				binary	decimal
valve (0S2)	1	cylinder (3A)	+	001	1
valve (0S3)	+	cylinder (3A)	-	000	0
valve (0S2)	1	cylinder (3A)	+	001	1
valve (0S4)	=	cylinder (3A)	-	000	0
		cylinder (2A)	+	010	2

Activation of valve (0S2) (input value 1) reverses the memory (0V19). A continuous signal is applied to port A1 of the adder (0Z3). The final control element (3V1) is reversed via the binary adder. Cylinder (3A) extends.

If the "+" key (0S3) is pressed, valve (0V16) closes, memory 1 (valve (0V18) and valve (0V19)) becomes inactive, there is no longer a signal applied at the binary adder (0Z3). Cylinder (3A) retracts. Memory 2 (valve (0V20) and valve (0V21)) are activated via valve (0V17). Likewise, switches (0V14) and (0V15) are reversed.

Renewed input of the value 1 (valve (0S2) actuated), reverses the memory valve (0V21). A signal is applied at port 4 of the adder. Cylinder (3A) indicates the input once again. When the "=" key (0S4) is pressed, memory 1 is activated again via the valve (0V16). There is still flow through valve (0V19). Thus, a continuous signal is applied at input A1 of the binary adder. This, together with the continuous signal from input 4 can reverse the final control element (2V1) via the dual-pressure valve (0V2) of the adder. Cylinder (2A) extends. The two continuous signals simultaneously reverse the pneumatic valve (0V8) via the dual-pressure valve (0V5). The final control element (3V1) exhausts. Cylinder (3A) retracts.

2. Addition: 1 + 2

Input		*Movement*		*Display value*	
				binary	decimal
valve (0S2)	1	cylinder (3A)	+	001	1
valve (0S3)	+	cylinder (3A)	-	000	0
valve (0S1)	2	cylinder (2A)	+	010	2
valve (0S4)	=	cylinder (3A)	+	011	3

Before entering the next addition, key (0S5) must be actuated, whereby all pneumatic signal valves of the memory processor (0Z4) are returned to their initial positions. Memory 1 (valves (0V18) and (0V19)) is active.

Input 1

Valve (0S2) is actuated, double pilot valve (0V15) has throughflow, double pilot valve (0V19) is reversed. A continuous signal is applied to output A1 of the binary adder via valves (0V6) and (0V8). Cylinder (3A) extends.

Input +

Valve (0S3) is actuated, memory 1 (valve (0V18) and valve (0V19)) becomes inactive, memory 2 (valve (0V20) and valve (0V21)) is activated. Switch (valve (0V14) and (0V15)) is reversed. There is no longer a signal at control air port 14 of the final control element (3V1). The valve is reversed by spring force. Cylinder (3A) retracts.

Input 2

Panel mounted valve (0S1) is actuated, pneumatic valve (0V14) has throughflow, memory valve (0V20) is reversed. A continuous signal is applied to port B2 of the binary adder. Cylinder (2A) extends.

Input =

Panel mounted valve (0S4) is actuated, pneumatic valve (0V16) reverses and thus memory 1 is active. Pneumatic valve (0V19) is still switched to flow from 1-4. A continuous signal is once again applied to port A2 of the adder (0Z3). Cylinder (3A) also extends.

Part D – Appendix

Data sheets

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3/2-way valve with selector switch, normally closed	152863
3/2-way valve with mushroom actuator	152864
3/2-way roller lever valve, normally closed	152866
Back pressure valve	152868
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3/2-way pneumatic valve, convertible	152871
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Linear drive, pneumatic	152890
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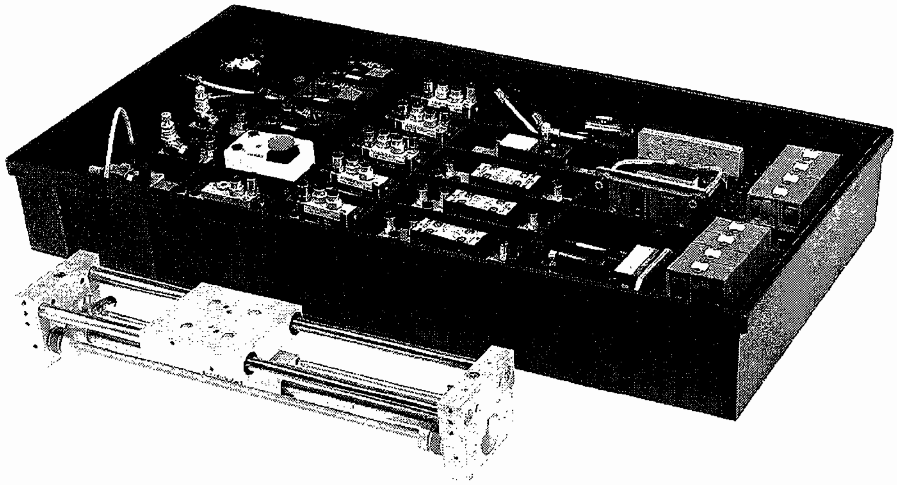
Storage tray

Equipment set TP102 in storage tray



The components of the equipment set for technology package TP102 are stored in the storage tray.

The storage tray serves both as a means of packaging for despatch and a drawer insertin the furniture range.

Mounting technology

The components of the equipment set are mounted on the Festo Didactic profile plate. The profile plate has 14 parallel T-grooves equally spaced 50 mm apart.

There are four alternatives for mounting the components on the profile plate:

Alternative A: Detent system, without additional facilities,
clamping mechanism with lever and spring,
which can be moved in the direction of the groove
for light, non load-bearing components

Alternative B: Rotational system, without additional facilities
triple grip nut with locking disc and T-head bolt,
vertical or horizontal alignment, for medium
load-bearing components

Alternative C: Screw-in system, with additional facilities,
cheese head screw with T-head nut,
vertical and horizontal alignment,
for heavy load-bearing components or
components which are rarely removed from the profile
plate

Alternative D: Plug-in system, with adapter,
Components for plug-in assembly boards with locating
pins, can be moved in the direction of the groove, for
light non-load bearing components.

Alternatively, the memory module and sequencer may also be mounted on the cabinet frame.

With **alternative A**, a slide engages in the T-groove of the profile plate. This slide is pre-tensioned by a spring. By pressing the blue lever, the slide is retracted and the component can either be removed or attached to the profile plate. The components are aligned with the groove and can be moved in the direction of the groove.

With **alternative B**, the component is secured to the profile plate by means of a T-head bolt and a blue triple grip nut. A locking disc is used for positional attachment, which can be attached in all four 90° directions. In this way, the components can be secured on the profile plate either parallel or across the groove.

When the locking disc has been adjusted to the required setting, the component is positioned on the profile plate. By turning the triple grip nut clockwise, the T-head nut is rotated by 90° in the T-groove by means of thread friction. Further turning of the triple grip nut clamps the component against the profile plate.

Alternative C is used for heavy components or components which are screwed on to the profile plate only once or seldom removed. Such components are secured by means of cheese head screws with hexagon socket and T-head nuts.

With **Alternative D**, the tried and tested ER units for plug-in assembly boards which have locating pins on a 50 mm grid, can be attached to the profile plate by means of adapters. One black plastic adapter is required for each locating pin. The adapters are inserted in the T-groove, positioned at intervals of 50 mm and secured by a rotation of 90°. The locating pins of the ER-unit are inserted in the adapter holes.

Plastic tubing

The polyurethane tubing provided is particularly flexible and kink-resistant.

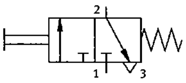
Technical data

Colour	silver metallic
External diameter	4 mm
Internal diameter	2.5 mm
Minimum bending radius within Temperature range of -35 to +60°C	17 mm
Maximum operating pressure in Temperature range of -35 to +30°C Temperature range of +30 to +40°C Temperature range of +40 to +60°C	 1000 kPA(10 bar) 900 kPA (9 bar) 700 kPA (7 bar)

Subject to alterations.

152860

3/2-way valve with pushbutton, normally closed



Design

The 3/2-way valve with push-in connections is assembled in a polymer housing. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative "A").

Function

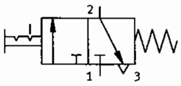
The valve is actuated by pressing the pushbutton. Releasing of the pushbutton returns the valve to the normal position via a return spring.

Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated) (or vacuum; port 1)
Design	Poppet valve, directly actuated on one side, with return spring
Actuation	Pushbutton
Pressure range	-95 – 800 kPa (-0.95 – 8 bar)
Standard nominal flow rate 1...2	60 l/min
Actuating force at 600 kPa (6 bar)	6 N
Connection	QSM-4 fittings for plastic tubing PUN 4 x 0.75

152863

3/2-way valve with selector switch, normally closed



Design

The 3/2-way valve with plug-in connections is assembled in a polymer housing. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

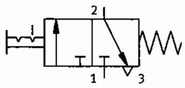
The valve is actuated by turning the selector switch. The switching status is maintained after the selector switch has been released. Rotating the selector switch to its basic setting, returns the valve to the initial position via a return spring.

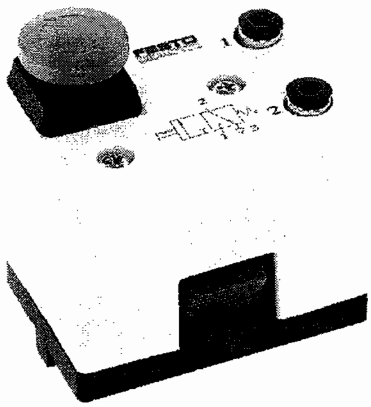
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	Poppet valve, directly actuated on one side, with return spring
Actuation	Selector switch
Pressure range	0 – 800 kPa (0 – 8 bar)
Standard nominal flow rate 1...2	60 l/min
Actuating force at 600 kPa (6 bar)	6 N
Connection	QSM-4 fittings for plastic tubing PUN 4 x 0,75

152864

3/2-way valve with mushroom actuator





Design

The 3/2-way valve with plug-in connections is assembled in a yellow polymer housing. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

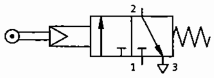
The valve is actuated by pressing the red mushroom actuator. The switching status is maintained after the actuator has been released. Rotation to the right returns the mushroom actuator to its normalposition and returns the valve to its initial position via the return spring.

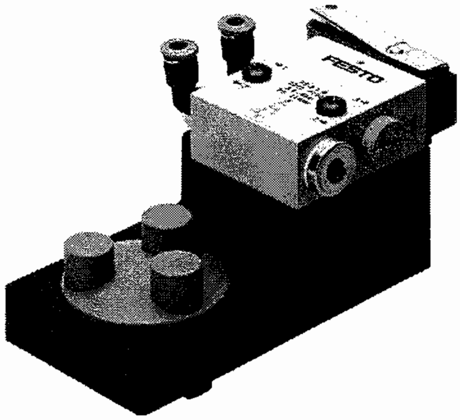
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	Poppet valve, directly actuated on one side, with return spring
Actuation	Mushroom actuator
Pressure range	-95 – 800 kPa (-0.95 – 8 bar)
Standard nominal flow rate 1...2	60 l/min
Actuating force at 600 kPa (6 bar)	6 N
Connection	QSM-4 fittings for plastic tubing PUN 4 x 0.75

152866

3/2-way roller lever valve, normally closed





Design

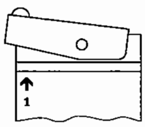
The 3/2-way roller lever valve with push-in elbow fittings is screwed onto a polymer base The unit is mounted on the profile plate via a rotary detent system with blue triple grip nut (mounting alternative "B").

Function

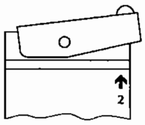
The valve is actuated by pressing the roller lever e.g. by means of cylinder trip cam. The valve is returned to the normal position via return spring after release of the roller lever.

Modification

This valve can be changed from "normally closed" (RS valve type) to "normally open" (ROS valve type).



Normally closed (RS valve type)
Actuator attachment at the left
(number 1 on the actuator attachment above number 1 on housing)



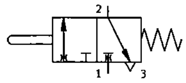
Normally open (ROS valve type)
Actuator attachment at the right
(number 2 on the actuator attachment above number 2 on housing)

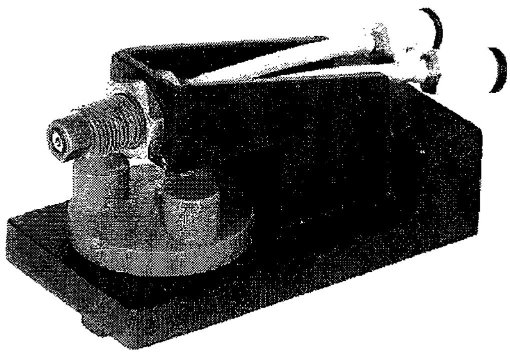
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	Poppet valve, directly actuated on one side, with return spring
Pressure range	280 – 800 kPa (2,8 – 8 bar)
Standard nominal flow rate 1...2	120 l/min
Actuating force at 600 kPa (6 bar)	1.8 N
Connection	QSML-1/8-4 fittings for plastic tubing PUN 4 x 0.75

152868

Back pressure valve





Design

The back pressure valve with poppet action and quick push-pull T-connectors is screwed on to an assembly base. The unit is mounted on the profile plate via a quick release detent system with blue triple grip nut (mounting alternative „B“).

Function

The back pressure valve with poppet action is actuated via the end face of the cylinder cam. If the stem is actuated, compressed air exhausts to atmosphere until the nozzle outlet is closed. At this point, a signal is generated at output 2 up to the level of the supply pressure. There is thus only low air consumption within the stem actuation range of 1 mm.

Note

The connections are identified according to the different tubing lengths:
1 = long tubing
2 = short tubing

The supply pressure can be regulated via a restrictor. Prior to the back pressure valve being used, a functional check should be carried out. If necessary, the back pressure valve can be adjusted to the cylinder end position by loosening the lock nut.

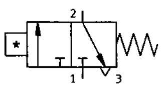
Comment

The output signal should be amplified if the supply pressure is very low.

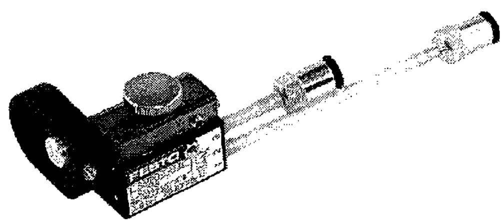
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Supply pressure range	0 – 800 kPa (0 – 8 bar)
Closing force at 600 kPa (6 bar)	12.5 N
Connection	QS-4 fittings for plastic tubing PUN 4 x 0.75

Pneumatic proximity switch



* actuated via permanent magnet



Design

The pneumatic proximity sensor switch comes equipped with push-in fittings and a mounting kit for attachment to cylinders.

Function

A permanent magnet attached to the cylinder piston actuates a pneumatic 3/2-way valve when overtravelled, thus triggering a control signal.

Note

The connections are identified according to the different tubing lengths:
1 = long tubing
2 = short tubing

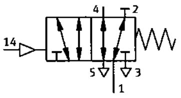
The pneumatic proximity switch complete with mounting kit, is attached direct to the cylinder barrel by clipping on the plastic fixture. The switch can be attached to a linear drive without this mounting kit. A reproducible switching accuracy of ±0.1 mm can be achieved, if the signal generator is approached from the connection side.

Technical data

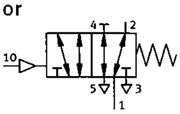
Pneumatic	
Medium	Compressed air, filtered (unlubricated) 40 µm, free of contamination
Design	Pneumatic signal generator for contactless position indication by means of magnetic field
Display	Visual position indication
Leakage (in 1)	Maximum 5 l/h, at 8 bar
Temperature range	-15 – +60 °C to DIN 40040
Mounting position	any
Pressure range	200 – 800 kPa (2 – 8 bar)
Signal pressure	corresponds to operating pressure
Bursting pressure	10 bar
Flow rate 1...2	Q_{nn} 40 l/min minimum
Flow rate 2...3	Q_{nn} 40 l/min minimum
Connection	QS-4 fittings for plastic tubing PUN 4 x 0.75

152871

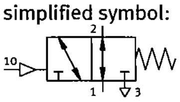
3/2-way pneumatic valve, convertible



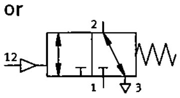
or

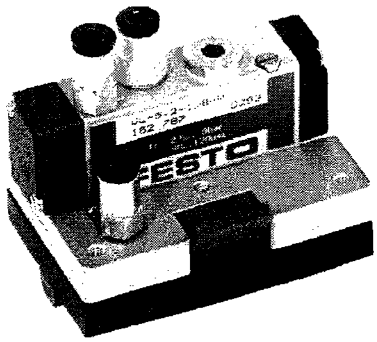


simplified symbol:



or





Design

The 5/2-way pneumatic valve with push-in connectors and a single blanking plug is screwed on to an assembly base, which is equipped with P-connection and silencers. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

The pneumatic valve switches at port 14 (Z) (10 (Z)) via a pneumatic signal and is returned to the initial position via a spring when the signal has been removed.

Note

The valve ports are identified by numbers:
1 = Supply port
2, 4 = Working or outlet ports
3, 5 = Exhausts (via silencers in function plate)
14, 10 = Pilot port

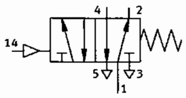
By blocking a working line (2 or 4), the 5/2-way valve can be converted into a 3/2-way valve:
Blanking plug in outlet 4 = normally open
Blanking plug in outlet 2 = normally closed

Technical data

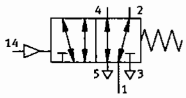
Pneumatic	
Medium	Compressed air, filtered
Design	Spool valve, indirectly actuated on one side, with return spring
Pressure range	250 – 1000 kPa (2.5 – 10 bar)
Standard nominal flow rate 1...4	500 l/min
Switching time at 600 kPa (6 bar)	On: 20 ms Off: 30 ms
Connection	QS-1/8-4-I, QSM-M5-4-I fittings for plastic tubing PUN 4 x 0.75

152872

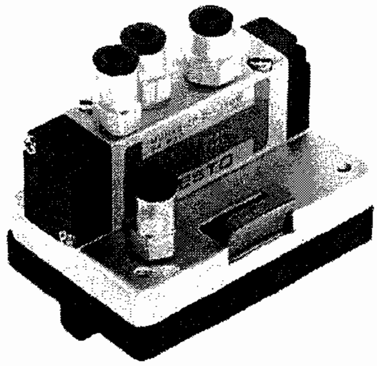
5/2-way valve



Symbol used in circuit diagrams.



The internal structure of this valve allows flowing of compressed air in both directions.



Design

The 5/2-way single pilot valve with push-in fittings is screwed onto the function plate, which is equipped with P-connection and silencers. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative "A").

Function

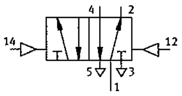
The single pilot valve is actuated by applying pressure at port 14 (Z). When the signal is removed the valve is returned to the normal position via return spring.

Technical data

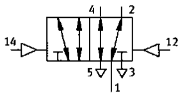
Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated) or vacuum
Design	Spool valve, directly actuated on one side, with return spring
Control pressure range	250 – 800 kPa (2.5 – 8 bar)
Operating pressure range	-90 – 800 kPa (-0.9 – 8 bar)
Standard nominal flow rate 1...2	500 l/min
Response time at 600 kPa (6 bar)	On: 20 ms Off: 30 ms
Connection	QS-1/8-4-I, QSM-M5-4-I fittings for plastic tubing PUN 4 x 0.75

152873

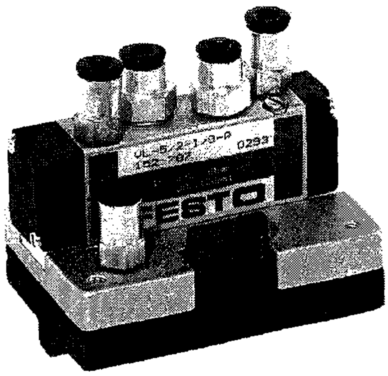
5/2-way double pilot valve



Symbol used in circuit diagrams.



The internal structure of this valve allows flowing of compressed air in both directions.



Design

The 5/2-way double pilot valve with push-in fittings is screwed onto the function plate, which is equipped with P-connection and silencers. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative "A").

Function

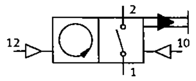
The double pilot valve is actuated by applying pneumatic signals alternately to ports 14 and 12. It remains in its last switched position until a counter signal is received.

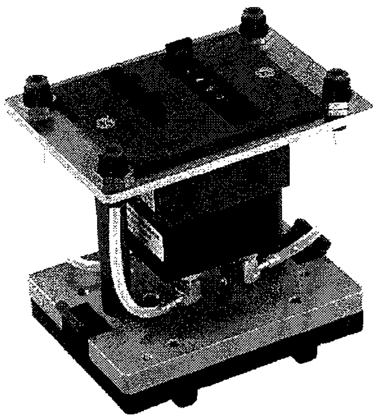
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated) or vacuum
Design	Spool valve, directly actuated on both sides
Control pressure range	150 – 800 kPa (1.5 – 8 bar)
Operating pressure range	-90 – 800 kPa (-0.9 – 8 bar)
Standard nominal flow rate 1...2, 1...4	500 l/min
Response time at 600 kPa (6 bar)	5 ms
Connection	QS-1/8-4-I, QSM-M5-4-I fittings for plastic tubing PUN 4 x 0.75

152877

Pneumatic preselect counter





Design

The pneumatic preselect counter with straight push-in fittings is fitted on a polymer base. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

The counter counts pneumatic signals downwards from a preselected figure. When the zero position has been reached, the counter emits a pneumatic output signal. This output signal is maintained until the counter is reset. The counter is pre-set by pressing the reset key (alongside the number window) and simultaneously keying-in (adjustment key on the counter roll) of the preselect value. The figure, once set, is retained whilst the counter is reset.

Note

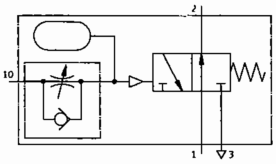
The valve ports are identified by numbers:
1 = Supply port
2 = Output signal
10 = Reset signal
12 = Counting signal

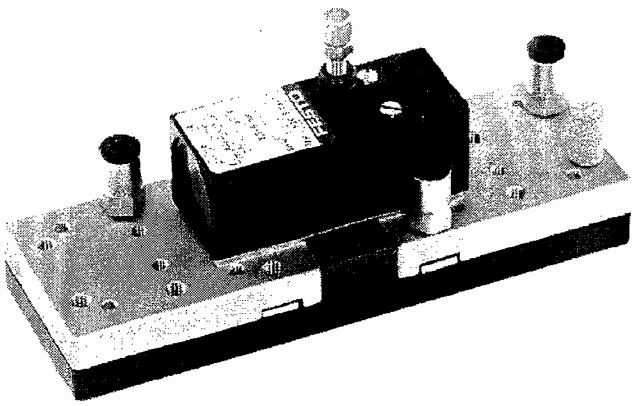
Technical data

Pneumatic	
Medium	Compressed air
Design	Mechanical counter with pneumatic drive
Display	5-digit, height of figures 4.5 mm
Reset	Push button or pneumatic signal
Pressure range	200 – 800 kPa (2 – 8 bar)
Minimum puls duration	Count: 10 ms, Reset: 180 ms
Counting rate continous operation	2 Hz
Anschluss	QSMS-4, QSML-M5-4 fittings for plastic tubing PUN 4 x 0.75

152878

Time delay valve, normally open





Design

The time delay valve is screwed on an assembly base equipped with straight push-in fittings. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

After the pilot signal is applied at port 10, a preset time elapses before the time delay valve is actuated. It returns to its initial position via a return spring once the signal is removed. The time delay is infinitely adjustable by means of a regulatig screw.

Note

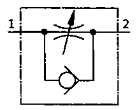
The valve ports are identified by numbers:

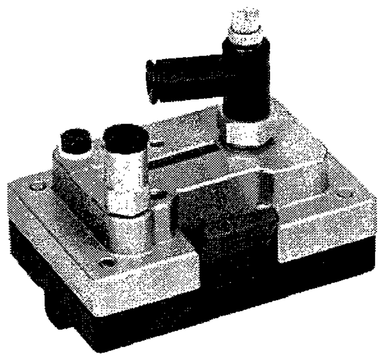
1 = Supply port
2 = Working or outlet port
3 = Exhaust
10 = Pilot port

Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	Poppet valve with return spring
Pressure range	0 – 800 kPa (0 – 8 bar)
Pilot pressure at 600 kPa (6 bar)	320 kPa (3.2 bar)
Standard nominal flow rate 1...2	65 l/min
Time delay	0.25 – 5 s (adjustable)
Connection	QSM-M5-4-I fittings for plastic tubing PUN 4 x 0.75

One-way flow control valve





Design

The adjustable one-way flow control valve is screwed into the function plate, incorporating a straight push-in fitting. The unit is slotted into the profile plate via a quick release detent system with a blue lever (mounting alternative “A”).

Function

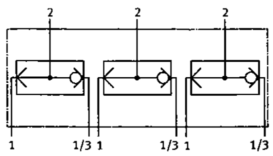
The one-way flow control valve consists of a combination of a flow control valve and a non-return valve.
The non-return valve blocks the flow of air in one direction, whereby the air flows via the flow control valve. The throttle cross section is adjustable by means of a knurled screw. The setting can be fixed by means of a knurled nut. Two arrows indicate the direction of flow control on the housing. In the opposite direction, the air flow is unrestricted via the non-return valve.

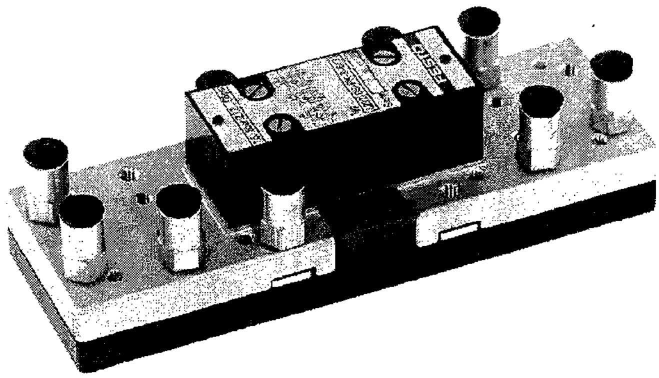
Technical data

Pneumatic	
Medium	Compressed air, filtered, (lubricated or unlubricated)
Design	One-way flow control valve
Pressure range	20 – 1000 kPa (0.2 – 10 bar)
Standard nominal flow rate	in throttled direction: 0 – 150 l/min free flow direction: 160 l/min (Throttle open) 130 l/min (Throttle closed)
Connection	QSM-M5-4 for plastic tubing PUN 4 x 0.75

152882

Shuttle (OR) valve, 3-fold





Design

The manifold consisting of three OR gates is screwed on to an assembly base equipped with the required straight push-in fittings. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

Each OR gate has two inlets (1, 1/3) and one output (2). The inlet which is not pressurised is automatically blocked. If different pressures are applied, then the higher pressure reaches the outlet (2).

Note

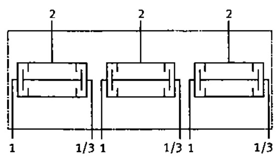
The valve ports are identified by numbers:
2 = Working or outlet port
1, 1/3 = Supply lines

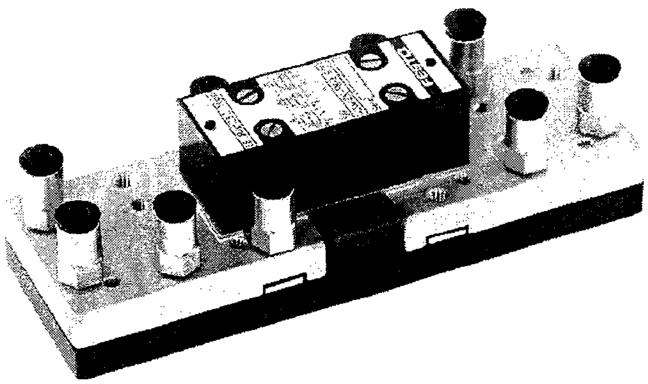
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	OR gate (shuttle valve)
Pressure range	160 – 800 kPa (1.6 – 8 bar)
Standard nominal flow rate 1, 1/3...2	100 l/min
Connection	QSM-M5-4-I fittings for plastic tubing PUN 4 x 0.75

152883

Dual pressure (AND) valve, 3-fold





Design

A manifold consisting of three AND gates is screwed on to an assembly base equipped with the required straight push-in fittings. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A").

Function

Each AND gate has two inlets (1, 1/3) and one outlet (2). Outlet (2) is only pressurised for as long as pressure is applied at both inlets. If different pressures are applied, then the lower pressure reaches outlet (2).

Note

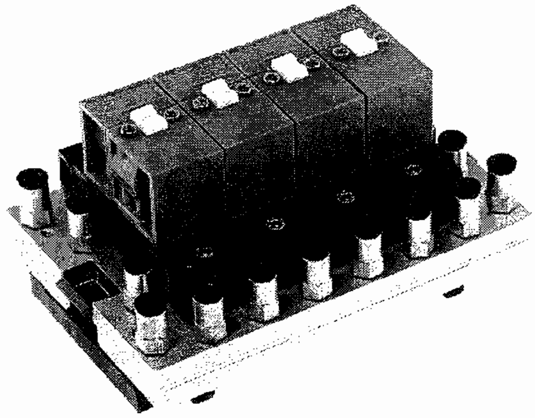
The valve ports are identified by numbers:
2 = Working or outlet port
1, 1/3 = Supply lines

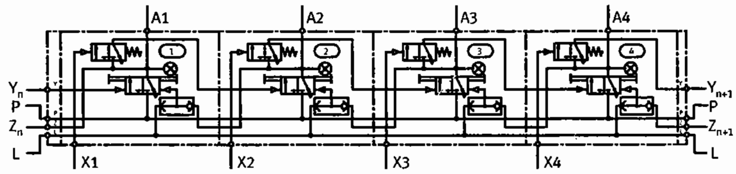
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	AND gate (dual pressure valve)
Pressure range	160 – 800 kPa (1.6 – 8 bar)
Standard nominal flow rate 1, 1/3...2	100 l/min
Connenction	QSM-M5-4-I fittings for plastic tubing PUN 4 x 0.75

152885

Stepper module, extension





Design

The four TAA stepper modules are screwed on to an assembly base equipped with the required straight push-in fittings. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

A Festo stepper sequencer is produced by linking together several basic modules, type TAA. This module consists of a memory (5/2-way double pilot valve) plus an AND and OR gate, and incorporates a visual switching indicator and manual override. The double pilot valve, with air applied at P, is actuated, i.e. reversed, via inlet Y. This produces a signal at outlet A for the intended switching step. In addition, this signal also resets a previous step, actuates the visual indicator and is applied to the AND gate. As soon as an acknowledgement signal of the initiated switching operation has been received at X, flow is opened at the AND gate and the following stepper module actuated via Y_{n+1}. An OR gate has been connected in series to port Z of the double pilot valve. By means of the signal Z_{n+1}, the pilot valve is reset by the following stepper module, i.e. the memory is cleared. The second inlet L can be used to return the entire sequencer to its starting position (e.g. for reset following an EMERGENCY-STOP).

152885

Stepper module, extension

Note

The expansion stepper module can only be used in conjunction with the stepper module. The valve ports are identified by letters:

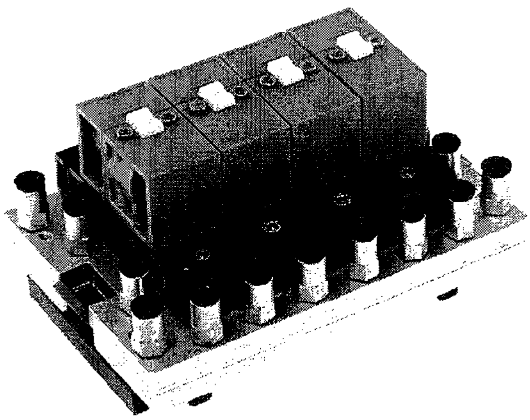
P = Supply port
A_1, A_2, A_3, A_4 = Outputs
X_1, X_2, X_3, X_4 = Acknowledgements
L = Reset (clear)
Y_{n+1} = Set: Output
Y_n = Set: Input
Z_n = Reset: Output
Z_{n+1} = Reset: Input

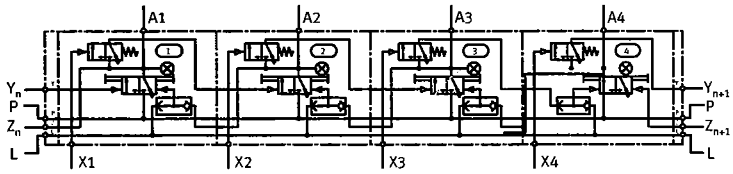
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	Poppet valve with integrated AND and OR gate
Standard nominal flow rate P...A	60 l/min
Pressure range	200 – 800 kPa (2 – 8 bar)
Connection	QSM-M5-4-I fittings for plastic tubing PUN 4 x 0.75

152886

Stepper module





Design

This unit consists of three TAA and one TAB stepper module which are screwed on to an assembly base, which is equipped with the required straight push-in fittings. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

In the case of module type TAB, an OR gate is positioned upstream of the Y_n inlet of the double pilot valve. If a signal is applied at Y_n or L, the valve is reversed and a signal appears at outlet A. In addition, this signal also resets the preceding stepper module, the visual indicator and the AND gate is supplied with pressure. When the acknowledgement signal reaches X, the AND flow is released and the signal Y_{n+1} appears. This signal is also maintained if the entire sequencer is reset at L and can thus be used for a renewed start. When the sequencer chain is started, the module is reset externally at port Z via the reset signal Z_{n+1} of the first module of the sequencer. With the TAA modules, an OR gate is connected upstream of port Z in the double pilot valve. This is why, in this case, the double pilot valve is returned via a signal at Z_{n+1} from the following stepper.

152886

Stepper module

Note

The valve ports are identified by letters:

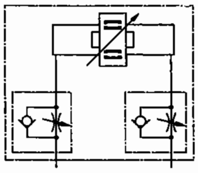
P	= Supply port
A_1, A_2, A_3, A_4	= Outputs
X_1, X_2, X_3, X_4	= Acknowledgements
L	= Reset (clear)
Y_{n+1}	= Set: Output
Y_n	= Set: Input
Z_n	= Reset: Output
Z_{n+1}	= Reset: Input

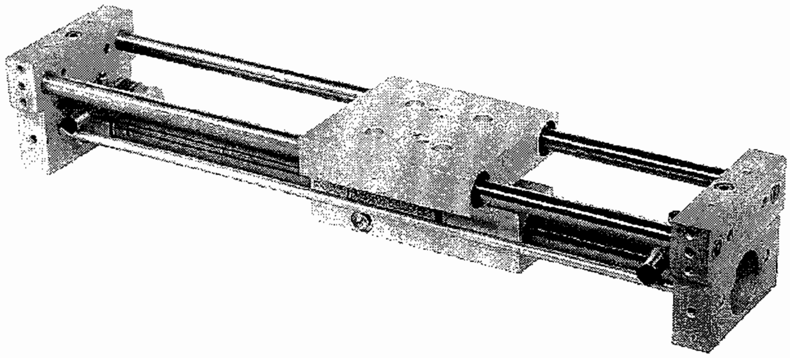
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	Poppet valve with integrated AND and OR gate
Standard nominal flow rate P...A	60 l/min
Pressure range	200 – 800 kPa (2 – 8 bar)
Connection	QSM-M5-4-I fittings for plastic tubing PUN 4 x 0.75

152890

Linear drive, pneumatic





Design

The linear drive is made up of a pneumatic drive (rodless cylinder) and a linear guide with slide.
The pneumatic drive is equipped with straight push-in fittings and adjustable one-way flow control valves. Pneumatic and electrical proximity switches for position sensing can be attached to the rods parallel to the piston rod. End position cushioning on both sides prevents the hard impact of the piston with the cylinder housing. The end position cushioning can be adjusted by means of two regulating screws.

Note regarding mounting

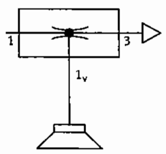
The linear drive can be mounted on the profile plate with the help of a mounting kit (mounting brackets, T-head nuts and cheese head screws), which is screwed on to the two yokes of the pneumatic drive (mounting alternative „C").

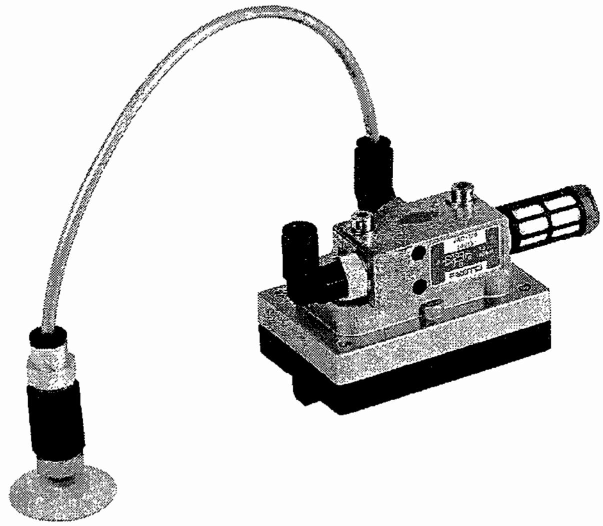
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	Double-acting rodless cylinder with magnetic coupling, two one-way flow-control valves with exhaust air flow control
Operating pressure	maximum 700 kPa (7 bar)
Stroke length	maximum 200 mm
Thrust at 600 kPa (6 bar)	90 N
Breakaway force of magnetic coupling	160 N
Connection	M5 QS-4 fittings for plastic tubing PUN 4 x 0.75

152891

Vacuum generator/suction cup





Design

The vacuum generator with push-in elbow fitting and suction cup is mounted on an assembly base. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

The vacuum generator creates vacuum when compressed air flows from ports 1 to 3 on the basis of the ejector principle. The suction cup is to be connected to vacuum connection 1_V. The suction process stops if the compressed air at 1 is switched off.

Note

The valve ports are identified by numbers:

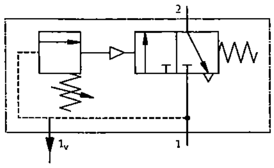
1 = Supply port
1_V = Vacuum connection
3 = Exhaust

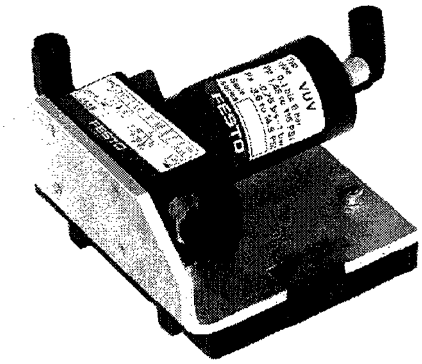
Technical data

Pneumatic	
Medium	Compressed air, filtered (lubricated or unlubricated)
Design	Ejector principle
Pressure range	150 – 1000 kPa (1.5 – 10 bar)
Vacuum at 600 kPa (6 bar)	Minimum 85 kPa (0.85 bar)
Air consumption at 600 kPa (6 bar)	15 l/min
Switching frequency at 600 kPa (6 bar)	Maximum 10 Hz with 1 m tube
Connection	QSL-1/8-4, QS-1/8-4-I fittings for plastic tubing PUN 4 x 0.75

152892

Adjustable vacuum actuator





Design

The adjustable vacuum actuator with basic valve and push-in elbow fitting is on an angle plate. The unit is mounted on the profile plate via a quick release detent system with blue lever (mounting alternative „A“).

Function

The adjustable vacuum actuator is used for the direct conversion of a vacuum signal into a normal pressure signal. As soon as the vacuum at connection 1_V has reached the value on the adjustable vacuum actuator, the attached basic valve is switched.

Note

The valve ports are identified by numbers:

1 = Supply or outlet port
1_V = Vacuum signal
2 = Working port

Technical data

Pneumatic	
Medium	Vacuum
Design	Valve actuator for vacuum-dependent actuation of pilot control
Vacuum range	-20 – -95 kPa (-0.2 – -0.95 bar) adjustable from -25 – -60 kPa (-0.25 – -0.6 bar)
Switching hysteresis	Maximum 20 kPa (0.2 bar)
Maximum pressure of the basic valve	800 kPa (8 bar)
Connection	QSL-1/8-4, QSML-M5-4 fittings for plastic tubing PUN 4 x 0.75

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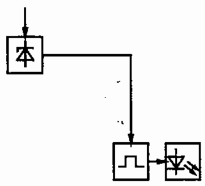

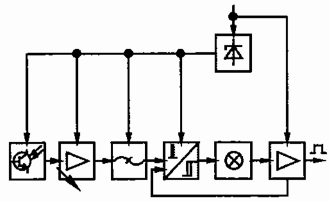

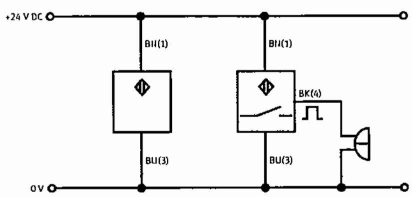

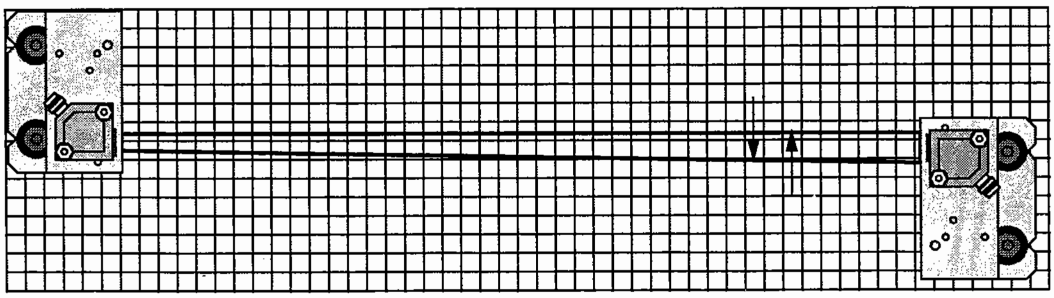

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