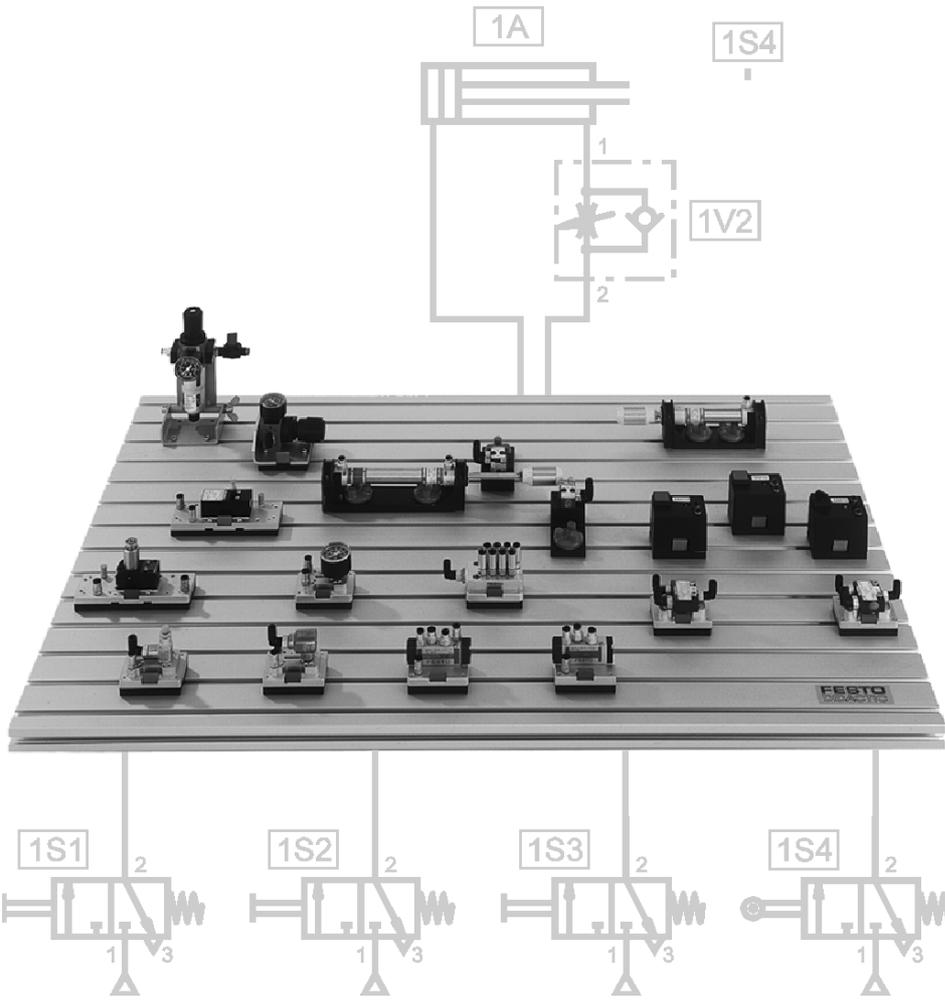


Pneumatics

Workbook Basic Level



FESTO

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Preface

The Learning System for Automation and Technology by Festo Didactic is formulated according to various training prerequisites and vocational requirements. It has been divided into the following 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 application technology (handling).

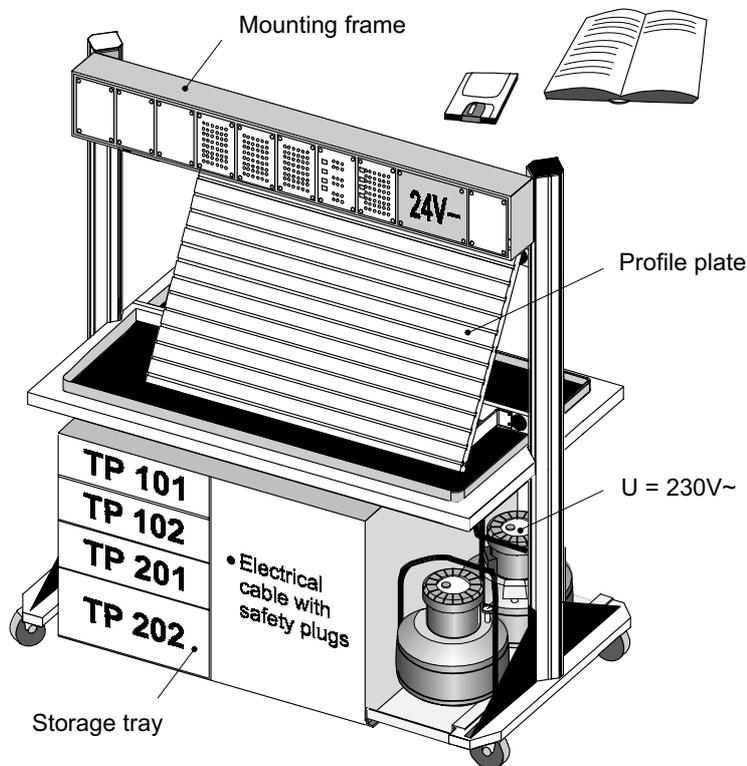


Fig. 1:
Pneumatics 2000 –
i.e. mobile workstation

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 TP 101

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 equipment lists
Part D	Appendix	Storage tray, mounting technology and datasheets

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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. Technology package TP100 deals exclusively with purely pneumatic controls.

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

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.

Precondition for assembling control circuits is a fixed workstation equipped with a Festo Didactic profile plate. The profile plate has 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) is recommended.

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 set of equipment for basic level TP101 enables the assembly of complete control systems for solving the problems set in the 20 exercises. The theoretical basis required for an understanding of this collection of exercises can be found in the following textbook:

Learning System for Automation and Technology

- Pneumatics, Basic Level

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



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 necessary!
- Releasing the CU quick push-pull connector: The tube can be released by depressing the collet (black ring) (releasing whilst pressurised is not possible!)
- Switch off the air supply before disconnecting the circuit.
- The mounting boards for the equipment are equipped with mounting alternatives A, B or C :

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 actuating 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 service unit with on-off valve). These components are attached by means of cheese head screws and T-head nuts.

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

A stop watch is required in order to evaluate the assembled circuits:

Stop watch

- 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 displacement-time diagrams for the assembled circuits.

Technology package for pneumatics (TP100)

The technology packages 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 technology package TP100 may also form part of the content of other packages.

Important components of TP100:

- Fixed workstation with Festo Didactic profile plate
- Practice and demonstration equipment
- Compressor (230 V, 0.55 kW, maximum 8 ar (= 800 Pa))
- Sets of equipment of single components (e.g. cylinder, directional control valves, preselect counters, stepper modules, vacuum installation, logic elements, linear drive)
- Optional training aids (e.g. pneumatic proximity switches, optical displays, pneumatic sequencer (Quickstepper), 5/3-way valve, pushing/pulling load)
- Practical models, complete laboratory installations

Practice and demonstration equipment

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 Sectional model set 1 + 2 with storage case Simulation software FluidSIM Pneumatics

Books and teaching media

<i>Seminars</i>	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 brought up to date and expanded. The sets of overhead transparencies, films and video cassettes, as well as the textbooks, are offered 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
- Logical AND/OR functions of the input signals
- Time-dependent control systems with time delay valve
- Pressure-dependent control systems with pressure sequence valves
- Fault finding in simple pneumatic control systems
- Safety regulations

Advanced level (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)

Description	Exercises																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Direct actuation of a single-acting cylinder	•	•	•	(•)																
Indirect actuation of single-acting cylinders									•				•							•
Direct actuation of double acting cylinders				•																
Indirect actuation of double acting cylinders					•	•	•	•		•	•	•	•	•	•	•	•	•	•	•
Creating an OR function						•		•	•	•		•		•					•	•
Creating an AND function					•	•	•	•			•	•		•	•	•	•	•	•	•
Time dependent control systems							•	•		•	•	•				•	•	•	•	(•)
Pressure dependent control systems a) Pressure sequence valve b) Pressure regulator								a b		b		b	b	a	b				b	a b
Use of limit valves (roller lever valves)					•	•	•		•	•	•	•	•	•	•	•	•	•	•	•
Signal switch-off through a) Roller lever valve with idle return b) Reversing valve											(a)				a	(b)	b	b	b	b
Control systems with continuous cycle							•	•			•		•							•
Oscillating cylinder movements										•						•				
Self-latching loop									•		•									(•)
Black-box problem solution																				•

() Training aims for later evaluation

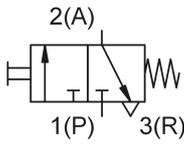
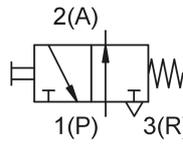
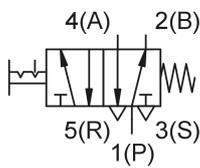
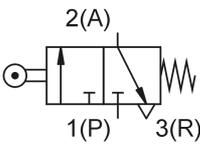
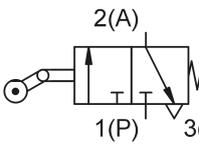
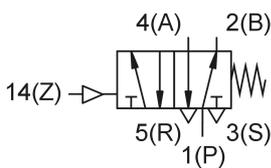
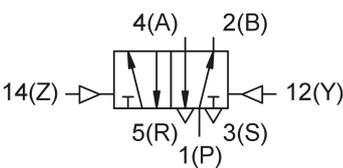
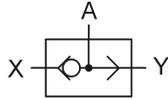
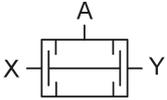
Set of equipment for basic level (TP101)

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

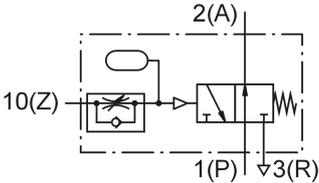
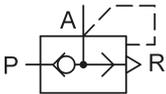
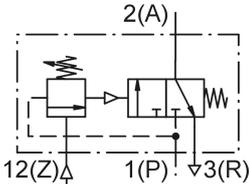
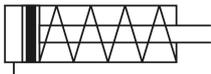
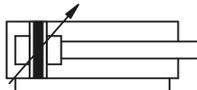
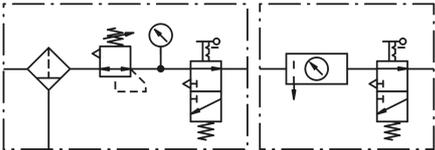
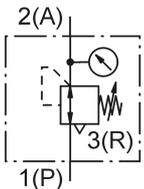
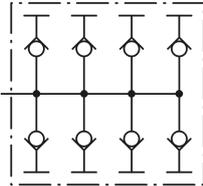
<i>Benennung</i>	<i>Bestell-Nr.</i>	<i>Menge</i>
Plastic tubing, 10 m, silver-metallic	151496	2
3/2-way valve with push button, normally closed	152860	3
3/2-way valve with push button, normally open	152861	1
5/2-way valve with selector switch	152862	1
Pressure gauge	152865	2
3/2-way roller lever valve, normally closed	152866	3
3/2-way roller lever valve with idle return, normally closed	152867	1
5/2-way single pilot 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
Service unit with on-off valve	152894	1
Pressure regulator with pressure gauge	152895	1
Manifold	152896	1
Connecting components	152898	1
Quick push-pull distributor	153128	10

*Set of equipment for
basic level (TP101)
(Order No.: 080240)*

Symbols of the equipment set

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

Symbols of the equipment set

<p>Time delay valve normally closed</p> 	<p>Quick exhaust valve</p> 
<p>One-way flow control valve</p> 	<p>Pressure sequence valve</p> 
<p>Single-acting cylinder</p> 	<p>Double-acting cylinder</p> 
<p>Service unit with on-off valve</p> 	<p>Pressure regulator with pressure gauge</p> 
<p>Manifold</p> 	<p>Connecting components</p> <ul style="list-style-type: none"> 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 the advanced level (TP102)

This set of equipment has been arranged for the purpose of advanced training in pneumatic control technology. Both sets of equipment (TP101 and TP102) contain components required for the teaching of the proposed syllabus aims and may be supplemented by other sets of equipment of the Learning System for Automation and Technology.

Set of equipment for
the advanced level
(TP102)
(Order No. 080241)

<i>Description</i>	<i>Order No.</i>	<i>Qty.</i>
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 pilot valve, convertible	152871	2
5/2-way single pilot valve	152872	2
5/2-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, expansion	152885	1
Stepper module	152886	1
Linear drive, pneumatic	152890	1
Adapter (for linear drive)	150519	1
Vacuum generator - suction cup	152891	1
Vacuum generator with ejector	152892	1
Connecting components	152898	1
Quick push-pull connector	153128	20

<i>Description</i>	<i>Order No.</i>
5/3-way single pilot valve, pneumatically actuated on both sides	152874
Pulling/pushing load	152889
Optical display	152893
Reservoir	152912

*List of additional
equipment for TP100*

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			2	3		1	1	1	1	2		1	2	1	1	1	1	1
3/2-way valve with push button, normally open			1						1											
5/2-way valve with selector switch				1			1	1			1		1					1	1	
Pressure gauge		2	2	2	2			1				2				2	2	2	2	
3/2-way roller lever valve, normally closed						1	2	2		3	2	4	2	3	2	3	3	2	4	4
3/2-way roller lever valve with idle return, norm. closed															2					
5/2-way single pilot valve					1				2		1						1	1	1	1
5/2-way double pilot valve						1	1	1		2	1	3	3	2	2	3	3	3	3	2
Shuttle valve (OR)						1		1	1	1	1	1		1				1	1	2
Dual pressure valve (AND)					1	1	1	1			1	1			1			3	1	4
Time delay valve, normally closed							1	1		1	1	1				1	1	1	1	
Quick exhaust valve			1		1											1				1
One-way flow control valve		1	1	2	1	1	2	1	2		1	2			2	2	2	2	2	1
Pressure sequence valve								1						1						1
Single-acting cylinder	1	1	1						1					1				1		1
Double-acting cylinder				1	1	1	1	1		1	2	2	2	2	2	2	1	1	2	2
Service unit with on-off valve	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	1		1			1	1	
Manifold	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Number of components	4	7	8	8	11	11	11	15	10	12	14	21	12	12	16	17	17	21	25	19
Number of components used for the first time	4	2	2	2	2	3	1	2	0	0	0	0	0	0	1	0	0	0	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 a control system on the profile plate. This direct interaction of theory and practice ensures rapid progress. The more detailed aims are listed in the table. Specific training aims are allocated to each exercise. Important follow up aims have been put in brackets.

■ **Time allocation**

The time required for working one's way through the problems set in the exercises depends on the previous knowledge of the students. Given a previous training as a skilled machinist or electrician: approx. 2 weeks. Given that of a technician or engineer: approx. 1 week.

■ **Component parts of the equipment sets**

The books of exercises and sets of equipment complement one another. For 15 of the 20 exercises, all you require are the components for basic level TP101. Assembly of the circuits for five of the exercises, however, requires a second set of equipment of the basic level.

Exercise 9: one additional 5/2-way pilot valve
(spring return)

Exercise 12: one additional roller lever valve

Exercise 15: one additional roller lever valve with idle return

Exercise 18: two further dual pressure valves

Exercise 20: one additional roller lever valve as well as three further dual pressure valves and an additional shuttle valve

For the practical assembly of exercise 15 (clamping camera housings), a pneumatically actuated optical indicator is desirable.

Alternative solutions are shown for exercises 15 to 19. These alternative circuits cannot, however, normally be constructed using solely components from TP101. To put these into practice, components from the set of equipment of the advanced level TP102 are required. Among the problems set for follow up purposes, there are also some which call for additional components. All the exercises at basic level can be mounted on the profile plate.

■ Forms of presentation

When showing motion sequences and switching states, use is made of abbreviated notation, possibly with division into groups as well as to motion diagrams. For exercises 6 to 20, the motion sequence is recorded by means of displacement-step diagrams with signal lines to VDI 3260. Up to exercise 5, a simplified presentation of the displacement-step diagram without signal lines is given for didactic reasons, but this too is in accordance with VDI 3260. The circuit structure in exercise 15 and 16 enables the creation of displacement time diagrams..

Methodical structure of the exercises

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

The two exercise sheets are divided into:

- Subject
- Title
- Training aim
- Problem

as well as

- Problem description
- Positional sketch.
- Positional sketch.

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

- Circuit diagram
- Motion diagram
- Solution description

as well as

- Circuit design
- Component list.

Some exercises have a follow up.

From exercise 15 onward, several alternative circuits provide an insight of greater depth into pneumatic control technology.

Part A – Course

Control systems with one cylinder **A-2**

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Control systems with one cylinder

Exercise 1 - 10

When controlling a cylinder, the following actions of piston and piston rod are possible:

- Forward stroke (from end position to end position)
- Return stroke (from end position to end position)
- Remain in the retracted end position
- Remain in the forward end position
- Motion reversal from an end position
- Motion reversal during part of a stroke
- Cylinder remains between the end positions (e. g. intermediate position)

The first six actions are put into practice in this chapter. The set of equipment for basic level TH101 consists of 19 different components (valves, cylinders, gauges, push buttons, etc.). The set contains some components in duplicate or even in triplicate. Within the first ten exercises, 18 of the 19 different components are used at least twice. (The roller lever valve with idle return comes into use in exercise 15.)

- 1 Allocating device**
- 2 Sorting device for metal stampings**
- 3 Separating parcel post**
- 4 Vertical switching point for briquettes**
- 5 Edge folding device**
- 6 Marking machine**
- 7 Separating out plain pins**
- 8 Foil welding drum**
- 9 Swithing point for workpieces**
- 10 Vibrator for paint buckets**

We hope you enjoy designing the circuits and assembling the control systems

Pneumatics

Allocating device

- Operation of a single-acting cylinder
- Direct actuation of a single-acting cylinder
- Use of a 3/2-way directional control valve
- Application of a service unit with on-off valve and manifold

- Drawing the displacement-step diagram in simplified form without signal lines
- Designing and drawing the displacement-step diagram with the help of the exercise description and positional sketch
- Comparing one's own solution with the one proposed
- Selection of the required components from the mobile laboratory workstation
- Insert the components selected in the Festo Didactic profile plate. It is advisable to arrange the components as on the circuit diagram
- Pipe up your circuit with the air pressure switched off
- Switch on air supply and carry out a function check
- Follow up (see part C)
- Dismantle your control system and put the components back in order in the mobile laboratory workstation

Subject

Title

Training aims

Problem

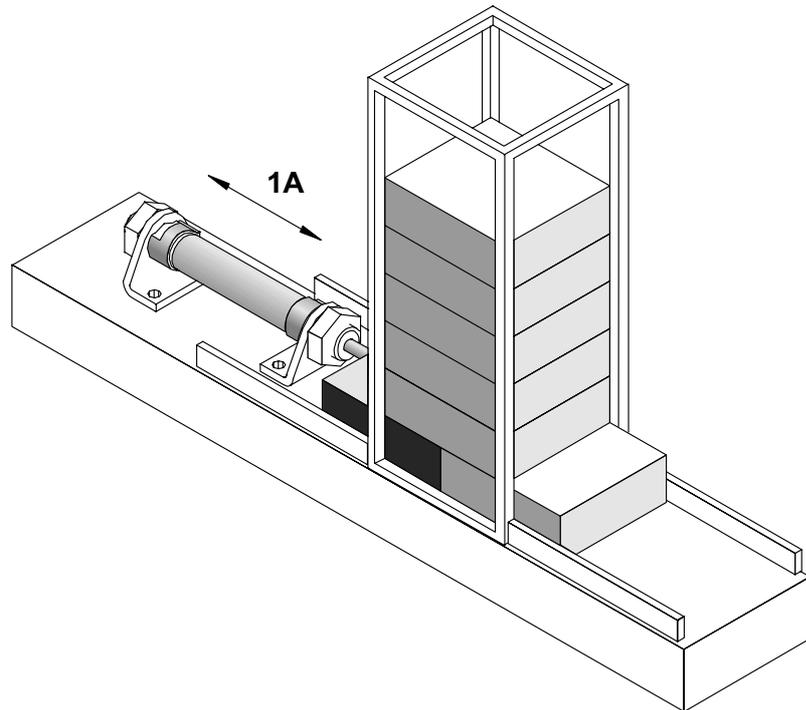
A-4

Exercise 1

Problem description The allocating device supplies aluminium valve blanks to a machining station.

By operating a push button, the piston rod of the single-acting cylinder (1A) is made to advance. After releasing the actuating button, the piston rod returns.

Fig. 1/1: Positional sketch



Pneumatics

Sorting device for metal stampings

- Direct actuation of a single-acting cylinder
- Operation of a 3/2-way push-button valve
- Connecting up and adjusting a one-way flow control valve
- Connecting up pressure gauges

- Drawing the displacement-step diagram (without signal lines)
- Designing and drawing the system circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Setting the duration of forward motion by means of the one-way flow control valve
- Noting the readings of the pressure gauges at steps 1 and 2
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

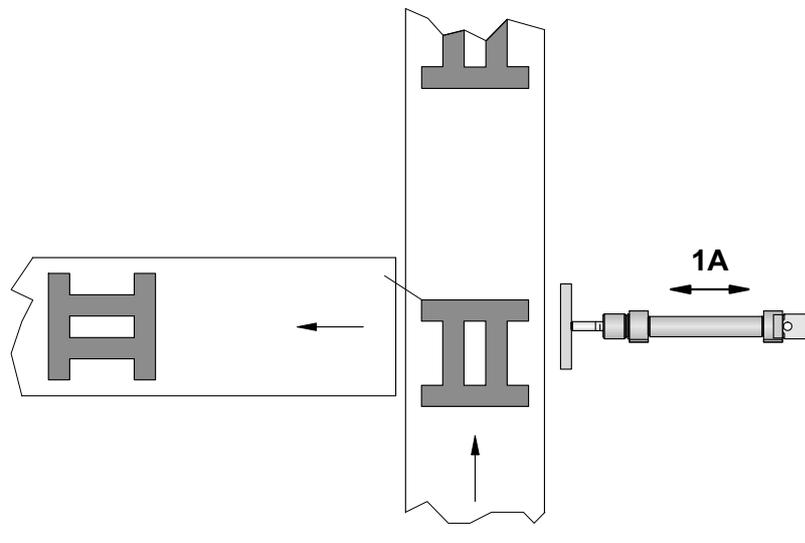
Problem

A-6

Exercise 2

Problem description Through operation of the push button on the actuating valve, metal stampings lying in random positions are sorted out and transferred to a second conveyor belt. The forward motion of the piston rod of a single-acting cylinder (1A) takes $t = 0.4$ seconds. When the push button is released, the piston rod travels to the retracted end position. A pressure gauge is fitted before and after the one-way flow control valve.

Fig. 2/1: Positional sketch
(Plan view)



Pneumatics

Separating parcel post

- Direct actuation of a single-acting cylinder
- Operation of a 3/2-way push button valve with flow in the normal position
- Realising that directional control valves exist both in the normally closed and normally open position
- Setting a one-way flow control valve
- Understanding the function of a quick exhaust valve

- Drawing the displacement-step diagram (without signal lines)
- Designing and drawing of the circuit diagram
- Comparing one's own solution with the one proposed
- Constructing the circuit
- Function check
- Adjusting the stroke time with the flow control valve
- Noting the readings of the pressure gauges at steps 1 and 2
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

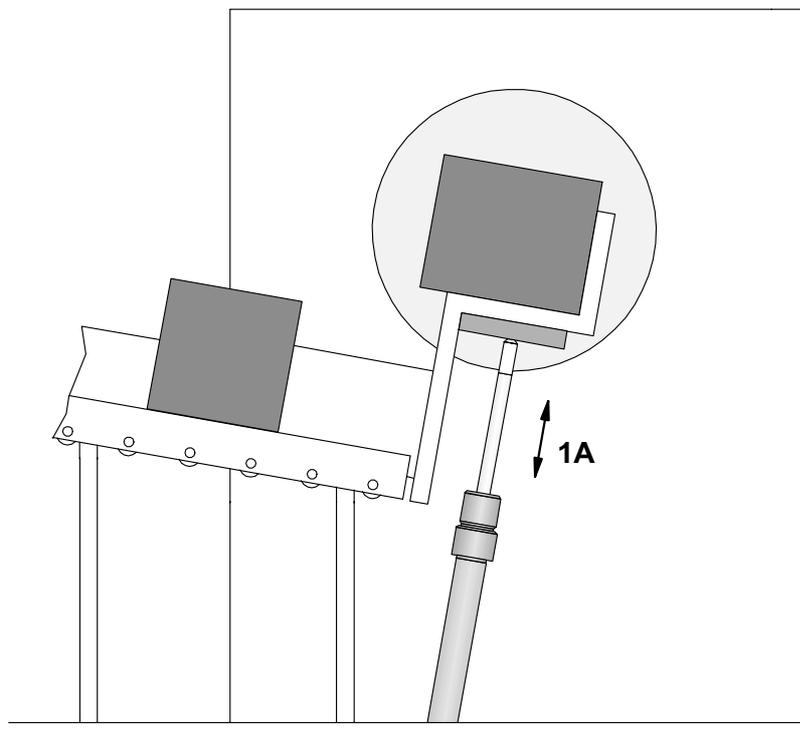
A-8

Exercise 3

Problem description The parcel separating device feeds parcel post from a sloping conveyor slide to an X-ray appliance.

Operating a push button causes very rapid retraction of the single-acting cylinder (1A) with the attached parcel tray. After releasing the valve actuator, the piston rod advances. Forward motion time $t = 0.9$ seconds. A pressure gauge is fitted before and after the one-way flow control valve.

Fig. 3/1: Positional sketch
(Side view)



Pneumatics

Vertical switching point for briquettes

- Direct actuation of a double-acting cylinder
- Operation of a 5/2-way valve with spring return and selector switch

- Drawing the displacement-step diagram (without signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Adjusting the stroke times using the one-way flow control valves
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

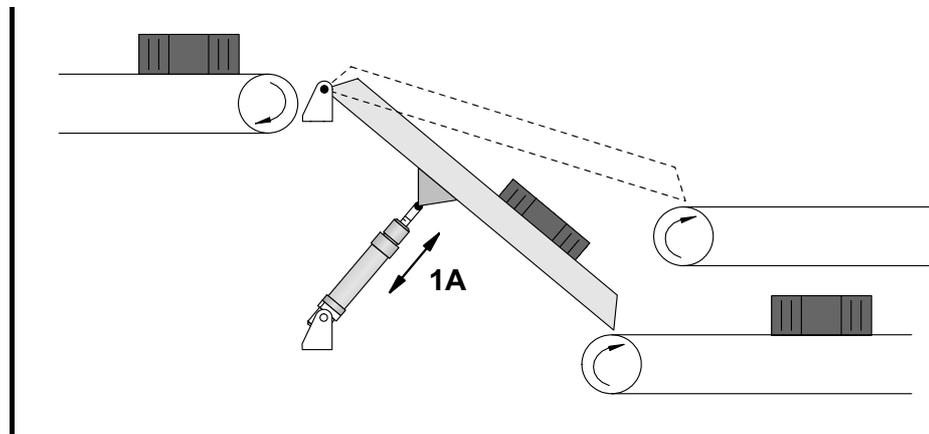
A-10

Exercise 4

Problem description With the help of the vertical switching point, soft cool (lignite) briquettes are to be fed to an upper or lower conveyor, according to selection.

The destination of the swivelling slide (upper or lower) is decided by means of a valve with selector switch. The upward motion of the double-acting cylinder (1A) is to take place in $t_1 = 3$ seconds; the downward motion in $t_2 = 2.5$ seconds. Pressure on both sides of the piston is indicated. In the initial position, the cylinder assumes the retracted end position.

Fig. 4/1: Positional sketch



Pneumatics

Edge folding device

- Indirect actuation of a double-acting cylinder
- Operation of a 5/2-way single pilot valve with spring return
- Application of a dual-pressure valve (AND-gate)
- Learning that a final control element can be influenced via an AND connection

- Drawing the displacement-step diagram (without signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

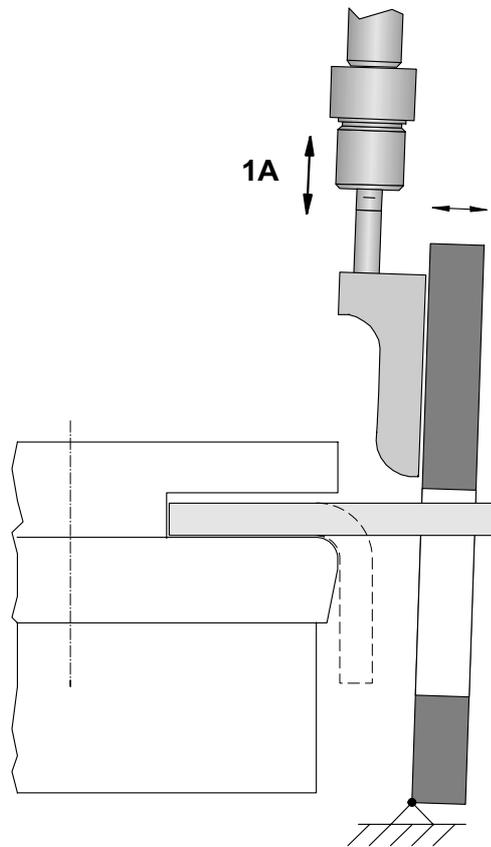
A-12

Exercise 5

Problem description Operation of two identical valves by push button causes the forming tool of an edge folding device to thrust downwards and fold over the edge of a flat sheet of cross sectional area 40 x 5.

If both – or even just one – push button is released, double-acting cylinder (1A) slowly returns to the initial position. The cylinder pressures are indicated.

Fig. 5/1: Positional sketch
(Side view)



Pneumatics

Marking machine

- Indirect actuation of a double-acting cylinder
- Operating a 5/2-way pneumatic double pilot valve
- Application of a shuttle valve (OR-gate)
- Realising that an actuator can be influenced via an OR-connection as well as an AND connection
- Application of a 3/2-way roller lever valve

- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Construction of circuit
- Function check
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

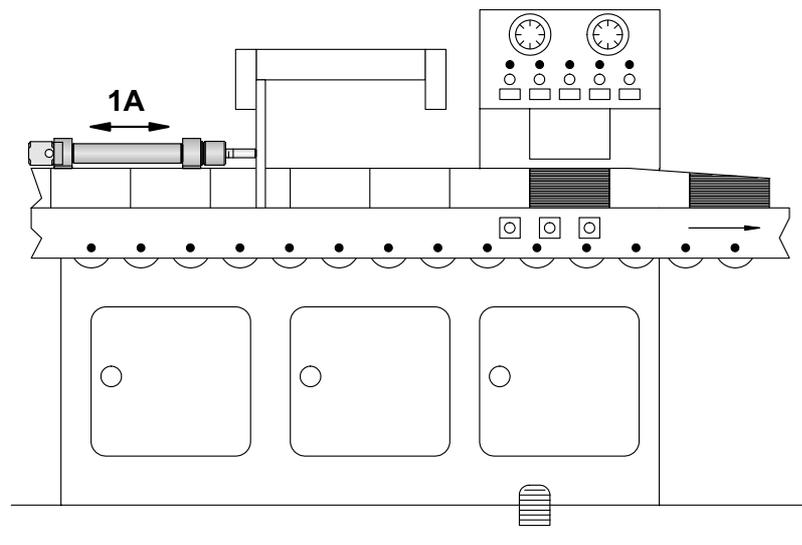
Problem

A-14

Exercise 6

Problem description Surveyor's measuring rods in 3 or 5 m length are marked in red with 200 mm graduations. There is a choice of two push buttons to start the forward movement of the measuring rods via cylinder (1A), which has the exhaust air throttled. The idle stroke, also started by a push button, can only take place when the double-acting cylinder (1A) has reached its forward end position.

Fig. 6/1: Positional sketch
(Front view)



Pneumatics

Separating out plain pins

- Indirect actuation of a double-acting cylinder with a bi-stable valve (memory)
- Application of a 5/2-way pneumatic bi-stable valve with manual override
- Use of a time-delay valve with normal position closed
- Design and construction of a control system with continuous to and fro movement (continuous cycle)

- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Adjusting the stroke times with the one-way flow control valves
- Adjusting the time delay valve
- Checking the time cycle
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

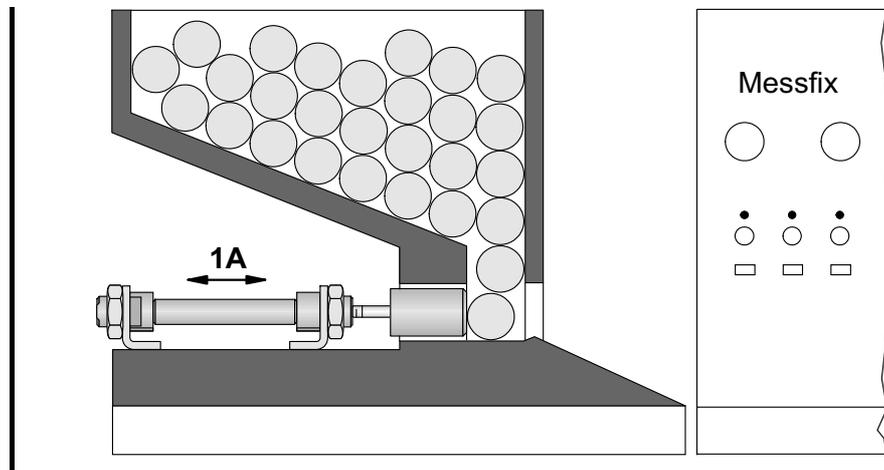
A-16

Exercise 7

Problem description A double-acting cylinder (1A) guides cylinder pins towards a measuring device. The pins are separated by means of a continuous to and fro movement. The oscillating motion can be started by means of a valve with selector switch.

The duration of the forward stroke of the cylinder is to be $t_1 = 0.6$ seconds, the return stroke $t_3 = 0.4$ seconds. The cylinder is to remain in the forward end position for $t_2 = 1.0$ seconds, resulting in a cycle time of $t_4 = 2.0$ seconds.

Fig. 7/1: Positional sketch



Pneumatics

Subject

Foil welding drum

Title

- Indirect actuation of a double-acting cylinder with a bi-stable valve
- Operating a pressure regulator to limit the piston force
- Use of a pressure sequence valve
- Realisation of a control system with single cycle and continuous cycle by means of a valve with selector switch

Training aims

- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Adjusting the time delay valve
- Adjusting the one-way flow control valve
- Adjusting the pressure regulator and the pressure sequence valve
- Dismantling and orderly replacement of components

Problem

A-18

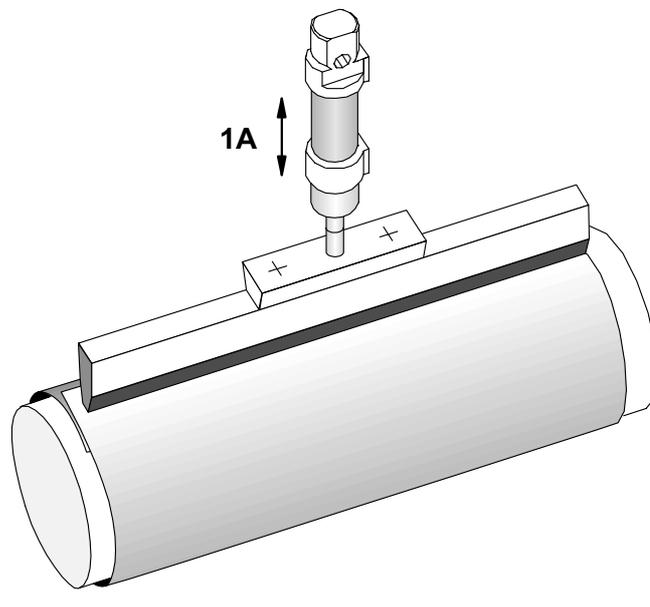
Exercise 8

Problem description An electrically heated welding rail is pressed onto a rotatable cold drum by a double-acting cylinder (1A) and welds a continuous plastic sheet into pieces of tubing. The forward stroke is triggered by means of a push button. The maximum cylinder force is set at 4 bar (= 400 kPa) via a pressure regulator with pressure gauge. (This prevents the welding rail damaging the metal drum.) The return stroke is not initiated until the forward end position has been acknowledged and the pressure in the piston area has reached 3 bar (= 300 kPa).

The supply air is restricted for the movement of the cylinder. The flow control should be adjusted so that the pressure increase to $p = 3 \text{ bar}$ (= 300 kPa) only takes place after $t_1 = 3 \text{ seconds}$, after the cylinder has reached the forward end position (the foil edges which are overlapped are welded by the heated welding rail as increased pressure is applied).

Restarting is only possible when the retracted end position has been reached and a time of $t_2 = 2 \text{ seconds}$ has elapsed. Reversing a 5/2-way valve with selector switch causes the control to be switched to continuous cycle.

Fig. 8/1: Positional sketch



Pneumatics

Switching point for workpieces

- Indirect actuation of a single-acting cylinder
 - Supply and exhaust air flow control of a single-acting cylinder
 - Development and construction of a self-latching circuit with “dominant off behaviour” (or “dominant on behaviour”)
 - Familiarisation with the abbreviated notation used to show cylinder movements
-
- Drawing the displacement-step diagram (with signal lines)
 - Designing and drawing the circuit diagram
 - Comparing one’s own solution to the one proposed
 - Construction of circuit
 - Function check
 - Adjusting the one-way flow control valve
 - Follow up
 - Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

A-20

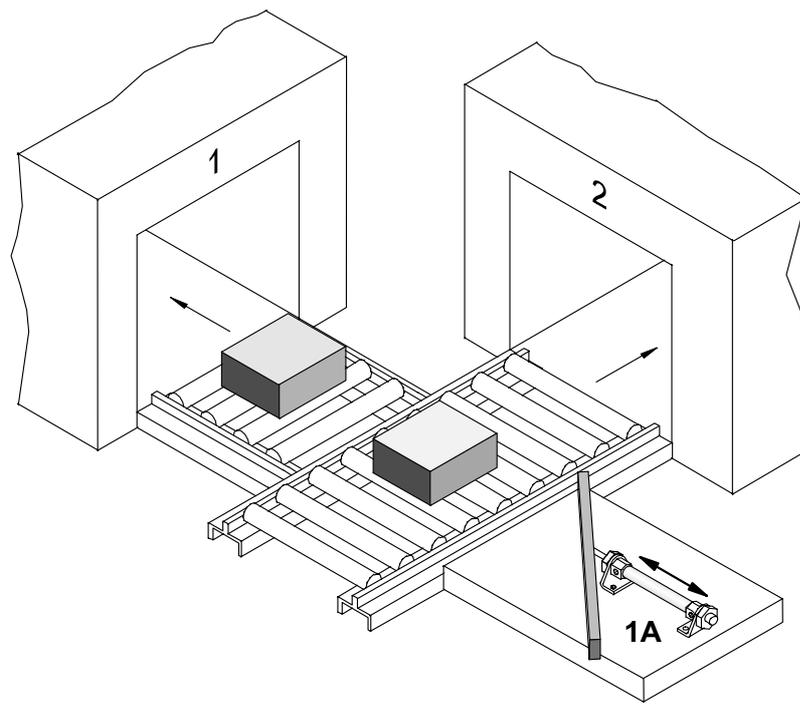
Exercise 9

Problem description Heavy die-cast blocks for power valves are to be fed to machine line 1 or 2. Brief actuation of a push button causes the single-acting cylinder (1A) to be extended with flow control. After a second push button has been actuated, the cylinder retracts with flow control. A single pilot valve with spring return is used as a final control element. Memorising of the advance signal is realised via a pneumatic self-latching circuit with “dominant off behaviour”.

Abbreviated notation

1A+	1A-
1A+	the piston rod of the cylinder (1A) extends.
1A-	the piston rod of the cylinder (1A) retracts.

Fig. 9/1: Positional sketch



Pneumatics

Vibrator for paint buckets

- Indirect actuation of a double-acting cylinder
 - Application of a roller lever valve in the central position of the piston rod
 - Realisation of a fast to and fro movement in the partial stroke range
 - Recognise that the oscillating frequency can be according to the flow rate
 - Construction of a pulse actuated signal input with a pneumatic memory (5/2-way pneumatic bi-stable valve)
-
- Drawing the displacement-step diagram (without signal lines)
 - Designing and drawing the circuit diagram
 - Comparing one's own solution to the one proposed
 - Construction the circuit
 - Function check
 - Adjusting the oscillating frequency via the flow rate supplied
 - Follow up
 - Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

A-22

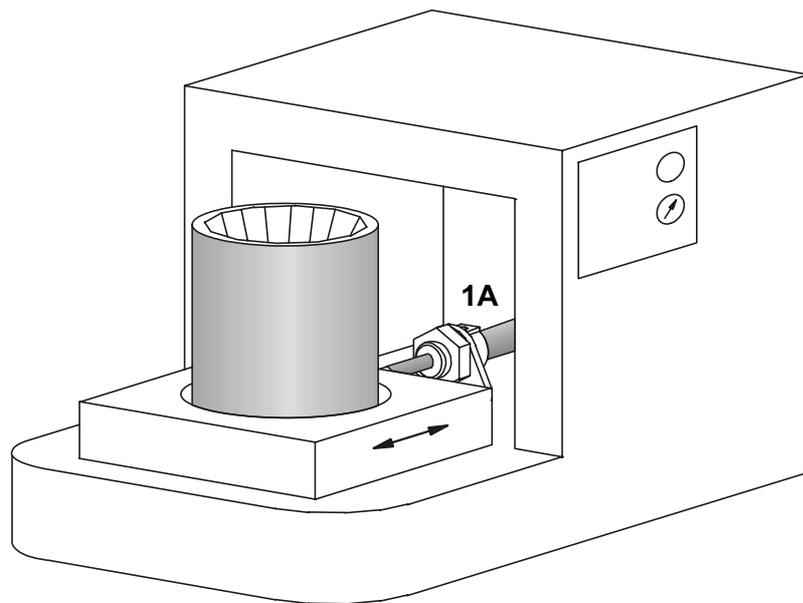
Exercise 10

Problem description After the liquid paint colours have been poured together into a bucket, they are mixed in by the vibrating machine.

When a push button has been pressed, the extended cylinder (1A) retracts completely and executes a to and fro movement in the rear stroke range. The oscillating is limited to the retracted end position by a roller lever valve as well as a second roller lever valve in the central position. The frequency of oscillating is adjustable within limits by setting a pressure regulator controlling the amount of air supply. Set an operating pressure of $p = 4 \text{ bar} (= 400 \text{ kPa})$.

After a specified interval, the oscillator is switched off. The double-acting cylinder extends completely and actuates the third roller lever valve. Set a vibration time of $t = 5 \text{ seconds}$.

Fig. 10/1: Positional sketch



Exercise 11 – 13

Control systems with parallel motions

In exercises 11, 12, and 13, two or three cylinders are controlled simultaneously. Cylinders either move in synchronisation or / and in a push-pull motion.

As the cylinders extend and retract, it is necessary to overcome frictional forces. Frictional forces limiting movement occur both between piston and cylinder wall and between piston rod and bearing bush. As these forces are generally not the same for the cylinders, synchronisation of the moving parts is only possible under certain conditions. This problem is shown in exercise 11. Exercise 12 and 13 are intended to offer a better insight into the matter.

11 Feed rail separator

Control of two double-acting cylinders in push-pull motion via a final control component.

12 Welding machine for thermoplastics

Control of two double-acting cylinders in synchronisation via two power valves and a final control element.

13 Quarry stone sorter

Control of two double-acting cylinders and a single-acting cylinder by three final control components and two roller lever valves.

Pneumatics

Feed rail separator

- Indirect control of two double-acting cylinders by one final control valve
- Design and assembly of a latching circuit with “dominant off behaviour”
- Establishing a back-up circuit for a time delay valve
- (Recognising the problems arising when cylinders are connected in parallel at low pressure)

- Drawing up the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one’s own solution with the one proposed
- Construction of circuit
- Function check
- Setting the time delay valve
- Setting the one-way flow control valve for time delay
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

A-26

Exercise 11

Problem description Turned parts for spark plugs are fed in pairs on a rail to a multi-spindle machining station. In order to achieve separation, two double-acting cylinders are triggered by one actuator in alternating push-pull rhythm. In the initial position, the upper cylinder (1A1) is retracted, the lower cylinder (1A2) in the forward position. Turned parts are resting against the second cylinder (1A2).

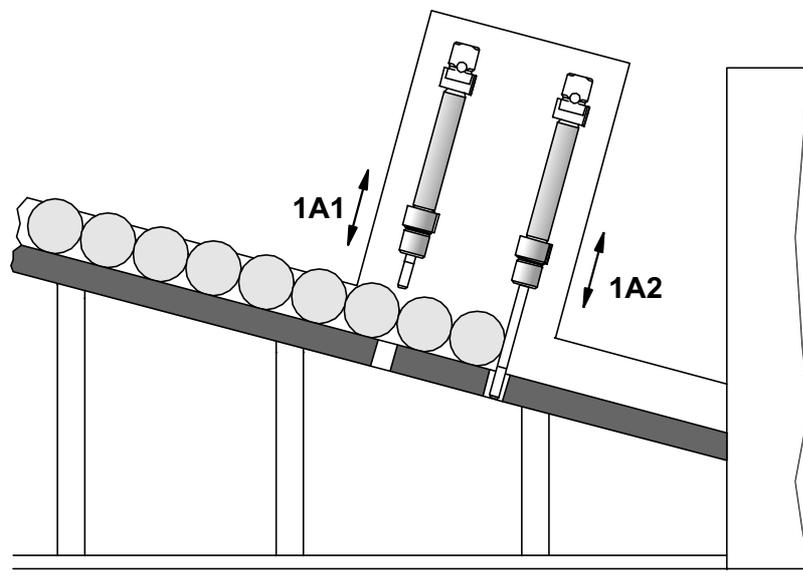
A starting signal causes cylinder (1A1) to advance and cylinder (1A2) to retract. Two sparking plug blanks roll onto the machining station. After an adjustable time of $t_1 = 1$ second, cylinder (1A1) returns and cylinder (1A2) advances at the same time. A further cycle can be started only when time interval $t_2 = 2$ seconds has elapsed.

The circuit is switched on by means of a push button valve. A detented valve makes it possible to change over from single to continuous cycle. The separating station must not restart on its own after a power failure.

Abbreviated notation 1A1+ 1A1-
1A2- 1A2+

In this abbreviated form of notation, movements which occur simultaneously are noted one underneath the other (1A1+, 1A2- or 1A1-, 1A2+).

Fig. 11/1: Positional sketch



Pneumatics

Subject

Welding machine for thermoplastics

Title

- Indirect actuation of two double-acting cylinders with two final control valves
- Use of a 5/2-way double pilot valve as control valve
- Parallel movement of two cylinders through adjustable exhaust air restriction
- Establishing an AND-function through a dual-pressure valve and through connecting roller lever valves in series

Training aims

- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Construction of the circuit
- Function check
- Setting the time delay valve
- Setting the pressure regulator
- Adjusting the one-way flow control valve for the parallel running of the cylinders
- Follow up
- Dismantling and orderly replacement of components

Problem

A-28

Exercise 12

Problem description Two double-acting cylinders (1A) and (2A) press together two electrically heated bars and, in doing so, join two thermoplastic sheets by welding. The thickness of the sheets varies between 1.5 mm and 4 mm. The seams may be of any length. The piston force of both cylinders is limited via a pressure regulator. Value set $p = 4 \text{ bar}$ ($=400 \text{ kPa}$).

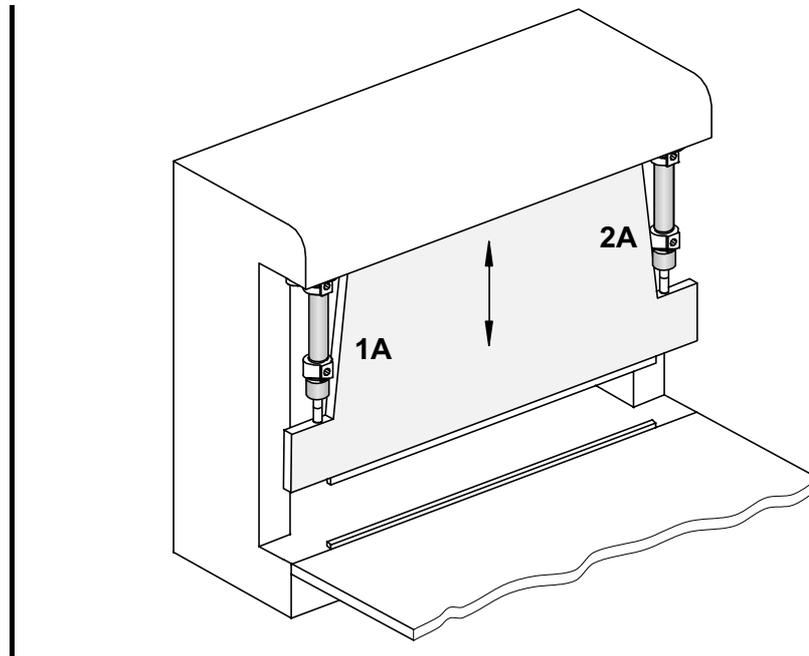
By actuating a push button, two double-acting cylinders are made to advance in parallel with their exhaust air restricted. To assist regulation, pressure gauges have been fitted between the cylinders and the one-way flow control valves. The end positions of the cylinders are interrogated.

After a time of $t = 1.5 \text{ seconds}$, the bar moves back to the initial position. The return stroke may be instantly initiated by means of a second push button.

Abbreviated notation

1A+	1A-
2A+	2A-

Fig. 12/1: Positional sketch



Pneumatics

Quarry stone sorter

- Indirekte Ansteuerung von zwei doppelwirkenden Zylindern und einem einfachwirkenden Zylinder mit je einem Stellglied
- Erkennen, daß die Rüttelfrequenz über die Luftmenge verändert werden kann
- Erkennen, daß man mit einem Signalgeber (Rollenhebelventil) mehrere Stellglieder beeinflussen kann.

- Write the abbreviated notation of the cylinder movements
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Adjusting the oscillating frequency by varying the quantity of air supplied using the pressure regulator
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

A-30

Exercise 13

Problem description Quarry stones are fed from a crushing roller to two vibrating sieves by means of an overhead conveyor belt. The fine upper sieves (1A) oscillates in opposing push-pull motion to the coarser lower screen (2A). The sieve oscillating frequency of the two double-acting cylinders is set to $f = 1$ Hz (Hertz) via the quantity of air supplied in load dependent relation. Reversal takes place in the retracted end positions via two roller lever valves. A third single-acting cylinder (3A) unclogs the sieves via two cables. The stone sorter is switched on and off by a valve with selector switch.

Fig. 13/1: Displacement-step diagram

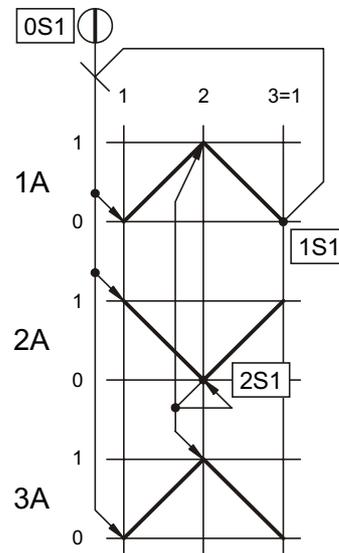
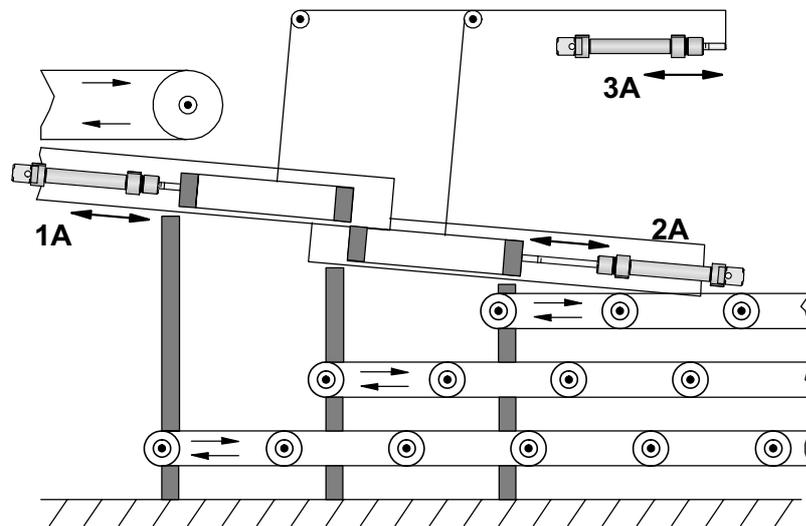


Fig. 13/2: Positional sketch



Exercise 14 and 15

*Control systems with
two actuators*

Exercise 14 is the first exercise in this series with two cylinders extending over more than two steps. The motion sequence is governed by limit switches (roller lever valves).

The main problem in exercise 15 is the cancelling of pilot signals no longer required at the final control valve. Locked-on pilot signals in sequential control systems can be influenced pneumatically by different means. One simple possibility is the fitting of roller lever valves with idle return. The use of reversing valves (auxiliary reservoirs) for switching off signals forms a further possibility (see alternative circuit B). In the course of the follow up to exercise 15, a displacement time diagram of the assembled system is shown for the first time.

14 Compactor for domestic rubbish

Activating two double-acting cylinders via two final control components. The final control valves are influenced by signal generators (selector switch, roller lever valve and adjustable pressure switch).

15 Clamping camera housings

Activating two double-acting cylinders via two final control components. The final control valves are influenced by signal generators (selector switch, roller lever valve and idle return roller lever valve).

Alternative circuit B: Control by means of a reversing valve.

Pneumatics

Compactor for domestic rubbish

- Learning how to interpret a displacement-step diagram with signal lines to VDI 3260
- Indirect activation of two cylinders with two final control valves
- Controlling the motion sequence with three roller lever valves
- Operating a pressure sequence valve

- Drawing up the abbreviated notation
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Setting the pressure sequence valve
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

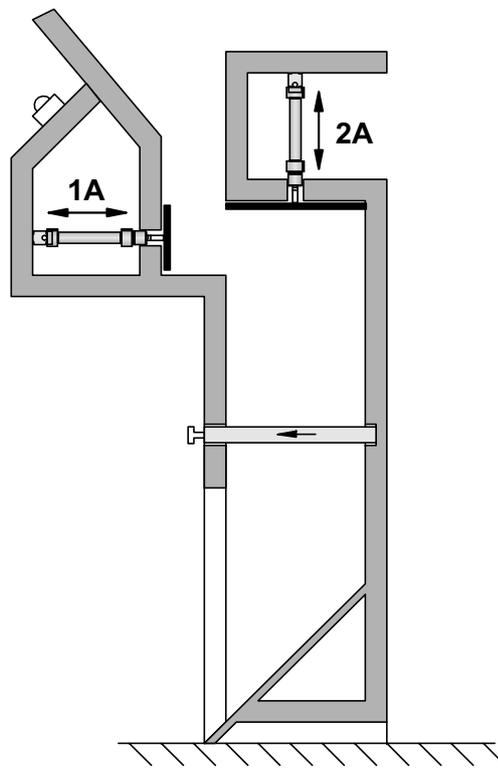
Problem

A-34

Exercise 14

Problem description The prototype of a pneumatic domestic rubbish compactor (under table model) is operated with a maximum working pressure of $p = 3\text{bar} = 300\text{ kPa}$. It is equipped with a pre-compactor (1A) including glass crusher as well as a main compactor (2A), which exerts a maximum force of $F = 2200\text{ N}$. When a start button is pressed, first the pre-compactor advances, then the main compactor. The subsequent return stroke of both double-acting cylinders takes place simultaneously. In the event that the main compactor does not reach the forward end position – rubbish bins full –, the return stroke of both cylinders is initiated by a pressure sequence valve. It is set to switch at $p = 2.8\text{ bar} = 280\text{ kPa}$.

Fig. 14/1: Positional sketch



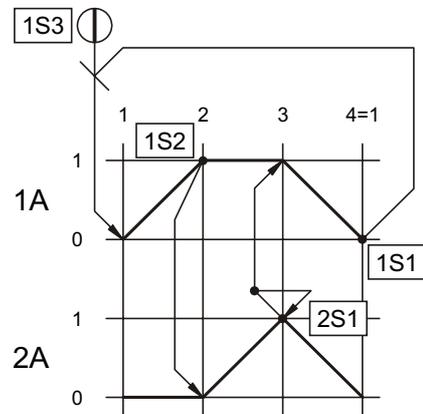


Fig. 14/2: Displacement-step diagram

A-36

Exercise 14

Pneumatics

Clamping camera housings

- Indirect activation of two cylinders with two final control valves
- Limitation of the maximum piston thrust through adjustment of working pressure
- Use of 3/2-way roller lever valve with idle return for signal cut-out
- Utilisation of a pneumatically actuated optical indicator
- (Recognising the problems arising from locked-on pilot signals – (signal cut-out))
- (Unassisted recording of the displacement-time diagram)
- (Recognising the functioning of a reversing valve)

- Drawing up the abbreviated notation
- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Setting the one-way flow control valves
- Setting the clamping pressure $p = 4 \text{ bar} = 400 \text{ kPa}$
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

A-38

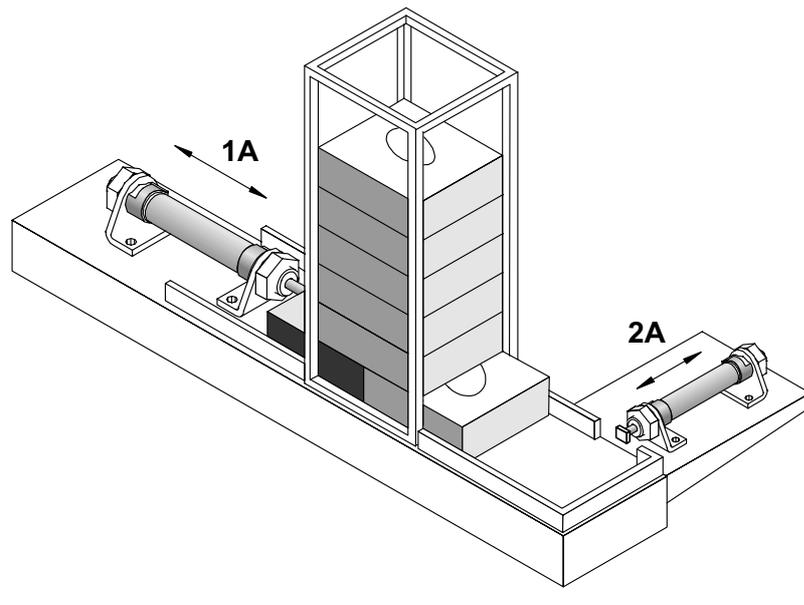
Exercise 15

Problem description When a push-button is operated, a pressure die-cast housing for a surveillance camera is fed from a magazine to a machining station by a double-acting cylinder (1A) and clamped.

A second, pressure restricted, double-acting cylinder (2A) then clamps the thin-walled housing from a direction of 90° to the first cylinder. The pressure regulator is set to $p = 4 \text{ bar} = 400 \text{ kPa}$. The cylinders move forward in $t_1 = t_2 = 1$. The completed clamping action is signalled by a pneumatically actuated optical indicator.

When the machining of the housing is finished, a second push button is operated. This causes an unthrottled return stroke of both cylinders in the reverse sequence.

Fig. 15/1: Positional sketch



Exercise 16 – 19

Control systems with reversing valves

In exercises 16 - 19, reversing valves (auxiliary memories, 5/2-way double pilot valves) are used for switching off signals. The advantage of reversing valve technology over systems with roller lever valves with idle return lies in the higher reliability of operation.

Several alternative circuits using reversing valves provide an insight into this circuit technology. In exercise 18, the cylinder carries out a double motion (1A+ 1A- 1A+ 1A-). For this, a division into four groups is necessary which is achieved by connecting three reversing valves in series. However, nowadays only circuits with one or two reversing valves are designed.

An even higher level of operational reliability is achieved by employing stepper modules from the set of equipment for advanced course TP102 of Learning System for Automation and Technology. (See alternative solution D, exercise 16, alternative solution C, exercise 17 and alternative solution B, exercise 18).

Within the scope of the follow-up to exercise 16, a displacement-time diagram of the assembled circuit is drawn up for the second time.

16 Input station for laser cutter

Activation of two double-acting cylinders with two final control valves. The final control valves are influenced by a reversing valve (auxiliary memory) and several signal generators. Draw up a displacement time diagram of the assembled control.

Alternative circuit B: Control system with reversing valve and active signal generators

Alternative circuit C: Control system using roller lever valve with idle return

Alternative circuit D: Control system with stepper module (circuit diagram, circuit design)

17 Partial automation of an internal grinder

Control of a linear feed with hydraulic cushioning cylinder (double-acting cylinder) and a single-acting cylinder with two final control valves. These final control elements are influenced by two reversing valves and several signal generators

Alternative circuit B: Control by two reversing valves and active signal generators

Alternative circuit C: Control system with stepper module

18 Drilling machine with four spindles

Control of a pneumatic linear feed unit with hydraulic cushioning cylinder (double-acting cylinder) via one power valve. The power valve is influenced by three reversing valves and several signal generators.

Alternative circuit B: Control by stepper module

19 Drilling machine with gravity magazine

Activation of three cylinders (double-acting cylinder, pneumatic linear feed unit with hydraulic cushioning cylinder and single-acting cylinder) with three final control elements. These power valves are influenced by one reversing valve and several signal generators.

Alternative circuit B: Control by two reversing valves and active signal generators.

Pneumatics

Input station for laser cutter

- Indirect activation of two cylinders with two final control valves
- Application of a reversing valve for switching off signals
- Re-arrangement of the teaching content of preceding exercises
- (Unassisted recording of the displacement-time diagram)
- (Recognising advantages and disadvantages of alternative circuits)

- Drawing up the abbreviated notation with division into groups
- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Setting the one-way flow control valves
- Setting the time delay valve
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

A-42

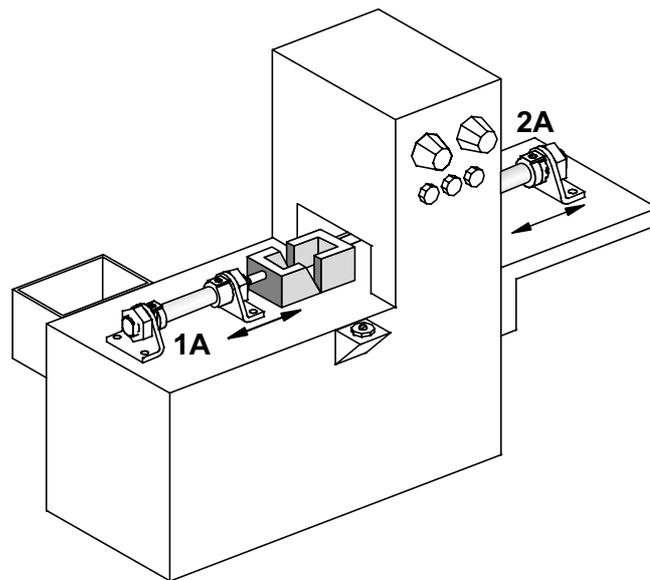
Exercise 16

Problem description Pieces of stainless steel sheet of 0.6 mm thickness are placed by hand into the input station. After a valve has been operated by push button, the ejector cylinder (2A) retracts with exhaust air restricted while, at the same time, clamping cylinder (1A) also advances with its exhaust air restricted; the sieve blank is pushed along and clamped. A cycle time of $t_1 = 0.5$ seconds is to be set for both cylinders.

During an adjustable clamping time of $t_2 = 5$ seconds, a laser cutting head produces a fine mesh sieve. After this operation, the clamping cylinder is retracted without restriction, following which the ejector cylinder pushes out the finished sieve, which is free of burred edges by a forward thrusting action.

The pressure lines P1 and P2 of the reversing valve are monitored with two pressure gauges.

Fig. 16/1: Positional sketch



Pneumatics

Partial automation of an internal grinder

- Indirect activation of two cylinders with two final control elements
- Designing and building a control system with two reversing valves for cancelling signals
- Re-arrangement of teaching content of previous exercises
- (Recognising the advantages and disadvantages of alternative circuits)

- Drawing up the abbreviated notation with division into groups
- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed.
- Constructing the circuit
- Setting the time delay valve
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

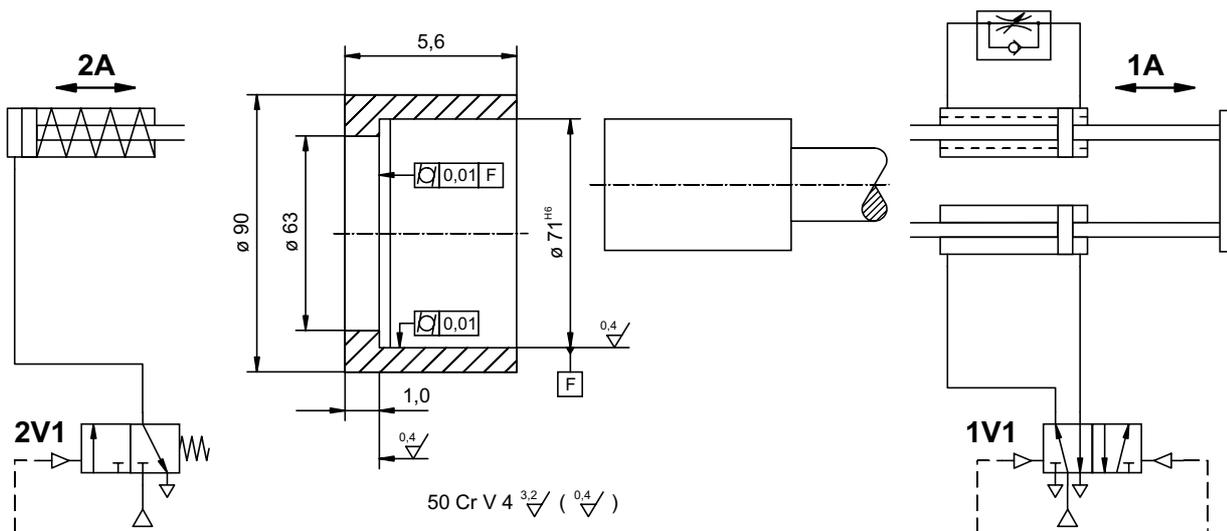
A-44

Exercise 17

Problem description Using a pneumatic linear feed unit with hydraulic cushioning cylinder, turned bearing bushes are internally ground, finished and ejected by means of a second cylinder.

After operating the push button of a signal input valve, pneumatic linear feed unit (1A) slowly advances for internal grinding and remains in the forward end position for $t = 2$ seconds for finishing. When the retracted end position is reached, a second roller lever valve is actuated and ejector cylinder (2A) advances. The single-acting ejector cylinder, which is activated by a power valve with spring return, sets in sequence its return stroke through a third roller lever valve. Pressure gauges are connected to lines P1 and P3.

Fig. 17/1: Positional sketch
(Bearing bush)



Pneumatics

Drilling machine with four spindles

- Indirect control of a double-acting cylinders
- Designing and constructing a control system with three reversing valves
- Re-arrangement of training content of previous exercises
- Independent formulation of the solution description
- (Realising the advantages and disadvantages of alternative circuits)

- Drawing up the abbreviated notations with division into groups
- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own circuit diagram to the one proposed
- Constructing the circuit
- Function check
- Setting the one-way flow control valves
- Setting the time delay valve
- Working out one's own solution description
- Comparing one's own solution description with the one proposed
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

A-46

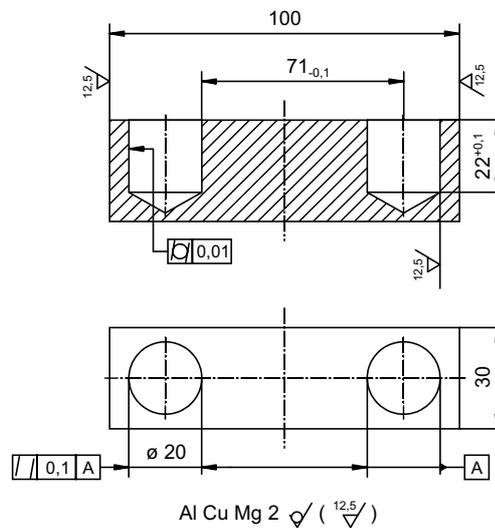
Exercise 18

Problem description To produce spacers using a four spindle drilling machine.

When a valve is actuated by foot pedal (simulated via push button), the four spindles of the drilling machine carry out a double movement. The feed unit with hydraulic cushioning cylinder (1A) is influenced by a final control valve with spring return. Control of the machine is effected by three reversing valves switching in sequence. To check the sequence, pressure gauges are attached to lines P1 and P4.

First, two pilot drillings of 8 mm diameter are carried out. Then, the four spindles return. Once the spacer has been repositioned, drillings of 20 mm diameter are made. The feed movement is heavily throttled; the return stroke is almost unrestricted. A pressure regulator determines the maximum cylinder force. Adjust pressure to $p = 4$ bar (400 kPa). Between the drill movements, the cylinder is held for $t = 1.5$ seconds in the retracted end position. Actuation of a foot actuated valve (simulated via selector switch) immediately initiates the return stroke or prevents advance of the drilling spindle.

Fig. 18/1: Workpiece drawing (Spacer)



Pneumatics

Drilling machine with gravity feed magazine

- Drawing up the abbreviated notation with division into groups
- Indirect control of two double-acting cylinders and a single-acting cylinder each with final control valve
- Design and construction of a control system with a reversing valve
- Re-arrangement of training content of previous exercises

- Drawing up the abbreviated notation with division into groups
- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the circuit diagram
- Comparing one's own solution to the one proposed
- Constructing the circuit
- Function check
- Setting the time delay valve
- Setting the pressure sequence valve
- Setting the pressure regulator
- Setting the one-way flow control valve
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

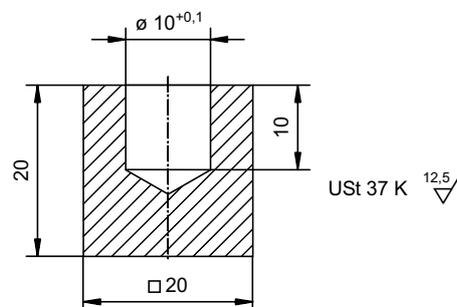


Fig. 19/1: Workpiece drawing (End piece)

A-48

Exercise 19

Problem description Square steel end pieces are fed from a gravity magazine to a drilling machine, clamped, machined and ejected.

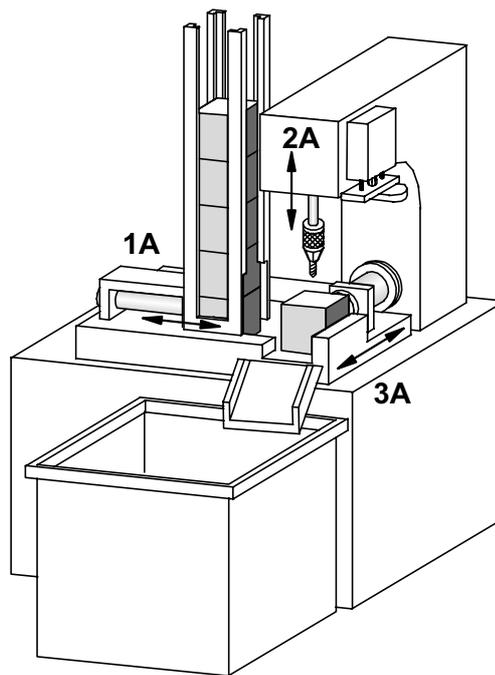
A horizontally installed double-acting cylinder with exhaust air throttling (1A) pushes end pieces out of a gravity feed magazine under the drilling spindle and holds them clamped against the fixed stop. When the required clamping pressure of $p = 4 \text{ bar}$ (400 kPa) has been reached, the drilling spindle (2A) extends via the feed unit with the hydraulic cushioning cylinder, exhaust air likewise throttled, for lowering the drill. The maximum feed force is set via a pressure regulator. It is set to $p = 5 \text{ bar}$ (500 kPa). After reaching the adjustable depth control stop established via a roller lever valve, the unthrottled return stroke is commenced.

Completion of the return stroke causes the finished end piece to be ejected by a single-acting cylinder (3A). After a period of $t = 0.6 \text{ seconds}$, the rapid return stroke is commenced. When the ejector cylinder has reached the retracted end position, a fourth roller lever valve is actuated; its signal can be used to indicate a new cycle. A separate pressure gauge indicates the clamping pressure of the cylinder (1A). A second pressure gauge is connected to line P2.

The control system is set in operation by pressing the start button. To select continuous cycle a detented valve is reversed.

Abbreviated notation 1A+ 2A+ 2A- 1A- 3A+ 3A-

Fig. 19/2: Positional sketch



Exercise 20

Logic control system

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

- actuators (e. g. double-acting cylinders)
- processors (e. g. dual-pressure valves)
- sensors (e. g. roller lever valves)

The binary figures zero and one can be shown by means of a cylinder.

- retracted cylinder signifies zero
- extended cylinder signifies one

With two cylinders it is possible to show four figures.

20 Pneumatic counter

Control of two double-acting cylinders via two final control valves.
The actuator is controlled by a processor. The processor receives signals from sensors giving the position of the actuators.

Pneumatics

Pneumatic counter

- Indirect control of two double-acting cylinders via two final control valves
- Solve the “black box problem” which has been set
- Application of the logic operations AND and OR
- (Design and construction of a pulse oscillator)

- Drawing up the abbreviated notation
- Drawing the displacement-step diagram (with signal lines)
- Designing and drawing the processor
- Drawing the complete circuit diagram
- Comparing one’s own solution with the one proposed
- Constructing the circuit with function monitoring
- Follow up
- Dismantling and orderly replacement of components

Subject

Title

Training aims

Problem

Problem description With two double-acting cylinders, it is possible to represent the binary statuses 00, 01, 10 and 11. Two final control valves (1V1) and (2V1) control the two counting cylinders (1A) and (2A). Four roller lever valves (1S1) and (1S2) as well as (2S1) and (2S2) report the statuses of the counting cylinders to the processor. The signal to continue (counting signal) is input with a push button (0S1).

Develop a purely pneumatic processor (3Z1) with four inputs and four outputs. The pneumatic counter is to increment by one digit with each signal input, e. g. from 2 to 3, from 3 to 0, from 0 to 1, from 1 to 2 etc.

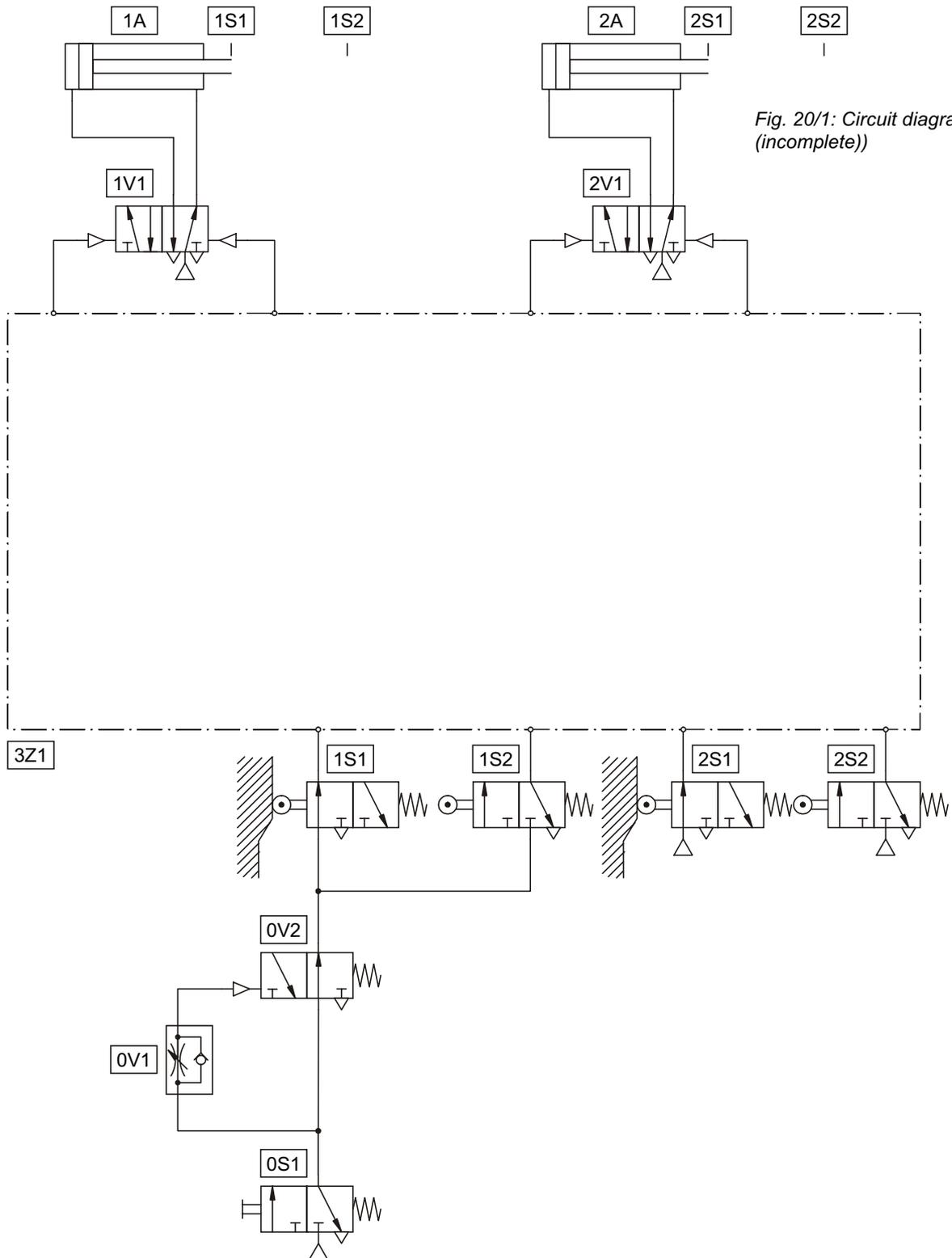


Fig. 20/1: Circuit diagram (incomplete)

A-54

Exercise 20

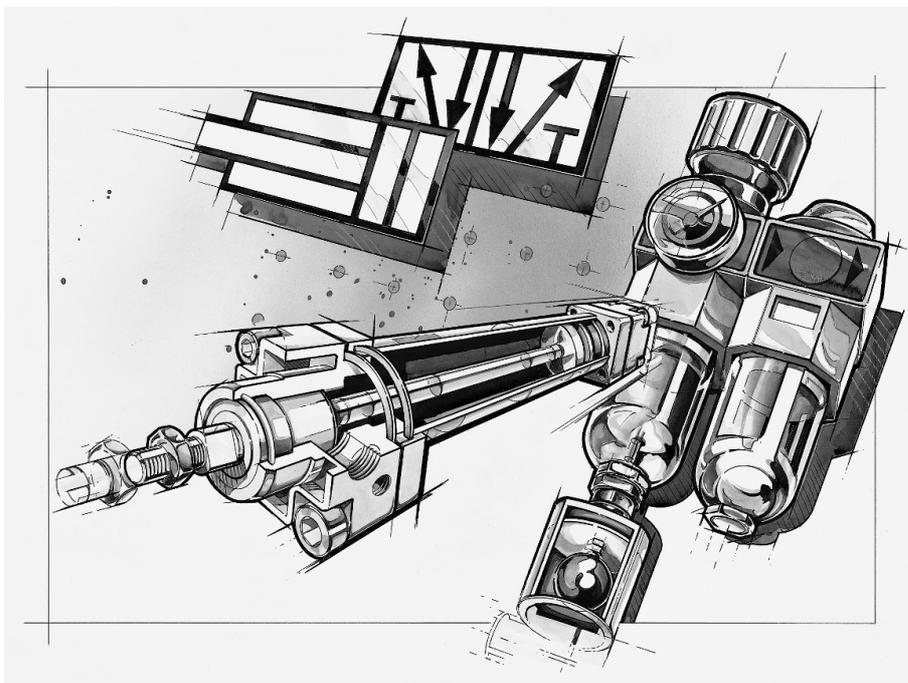
Part B – Fundamentals

The theoretical fundamentals for the training package Pneumatics, Basic Level are described in the textbook

Learning System for Automation and Technology

Pneumatics

Basic Level TP 101

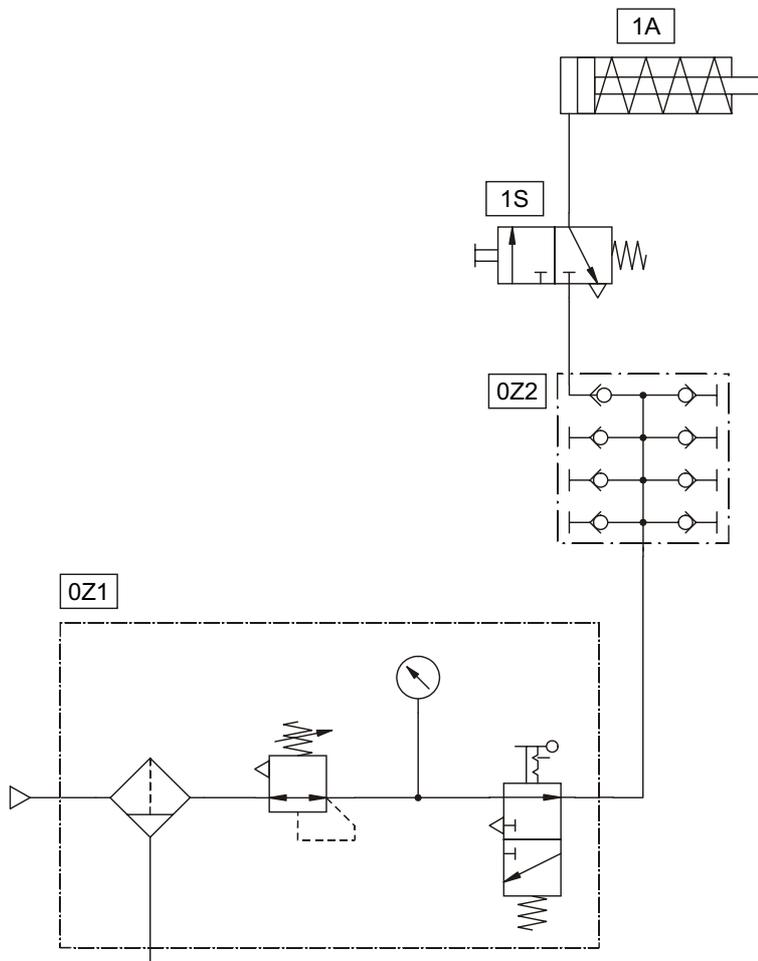


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Part C – Solutions

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Allocating device



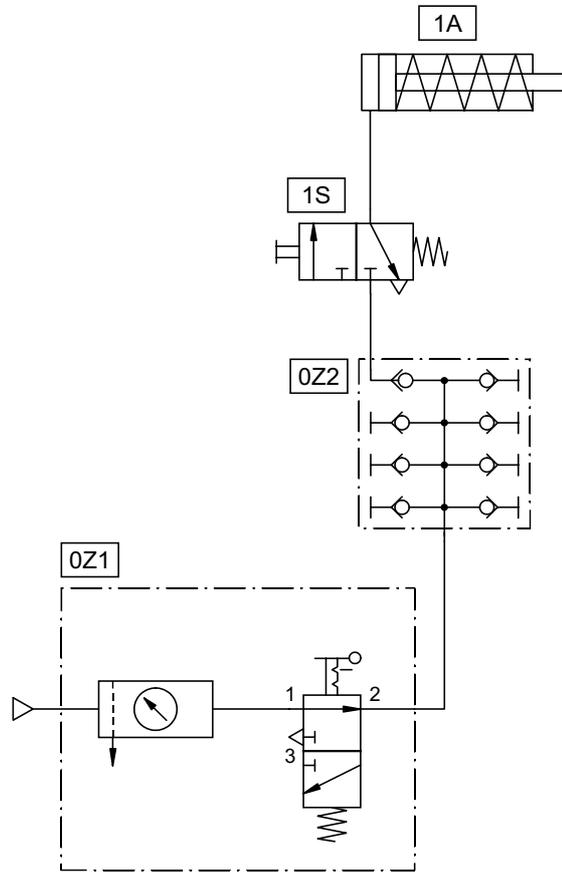
Detailed representation of service unit with on-off valve

Fig. 1/2a: Circuit diagram

C-4

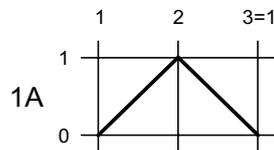
Solution 1

Fig. 1/2b: Circuit diagram



Simplified representation of service unit with on-off valve

Fig. 1/3: Displacement-step diagram



Simplified representation without signal lines¹

¹ Displacement-step diagram

From exercise 6 on, all diagrams are shown complete with signal lines.

The description of the solution makes reference to the circuit diagram and the displacement-step diagram. With regard to the circuit diagram, we distinguish between the detailed representation and the simplified representation.

Solution description

Service unit with on-off valve and manifold

Component (0Z2) represents the manifold (8 connections) (see also circuit design). Component (0Z1) symbolises the service unit and on-off valve.

Initial position (first vertical line in the motion diagram)

The initial position² of the cylinder and valves can be ascertained from the circuit diagram. The internal spring of cylinder (1A) holds the piston in the retracted end position. The volume of air in the cylinder is evacuated via the 3/2-way valve (1S).

Step 1-2

Through operating the 3/2-way valve (1S) via the push button, air is applied to the chamber on the piston rod side of cylinder (1A). The piston rod of the cylinder advances, and pushes a valve blank out of the magazine. If valve (1S) continues to be operated, the piston rod remains in the forward end position.

Step 2-3

After releasing the valve actuating button, the air in the cylinder is exhausted via the 3/2-way valve (1S). The force of the return spring pushes the piston back to its initial position. The valve blanks are supplied from the magazine by gravity.

Marginal condition

If the push button (1S) is briefly pressed, piston rod (1A) advances only part of the way and returns immediately.

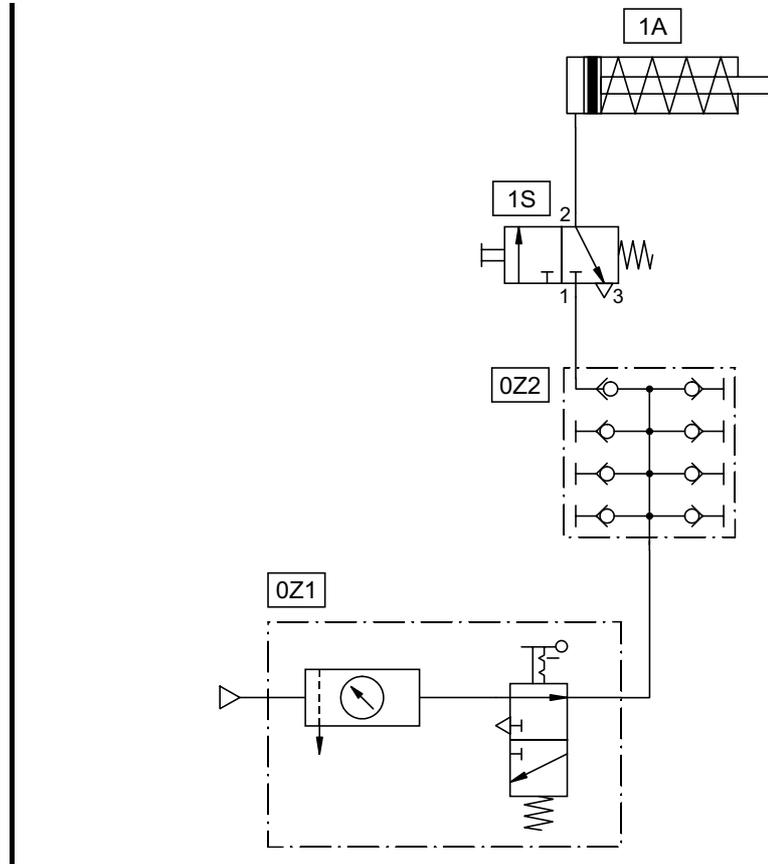
2 Initial position

The components assume the specified states required to start the sequence of operations, i.e. the on-off valve (0Z1) is switched on and the system pressurised. If the start button (1S.) is pressed, the piston rod of the cylinder (1A) advances.

C-6

Solution 1

Fig. 1/4: Circuit design



Components list

Components	Description
0Z1	Service unit with on-off valve
0Z2	Manifold
1A	Single-acting cylinder
1S	3/2-way valve with push button, normally closed



Apart from the above mentioned components, you will need the Festo Didactic profile plate on which to build the systems, as well as a source of compressed air.

Follow up

- Switch off the compressed air supply by means of the 3/2-way on-off valve (0Z1). Exchange the connections on the 3/2-way push button valve (1S).
- Re-check the operation of the control system after switching on the compressed air.

Sorting device for metal stampings

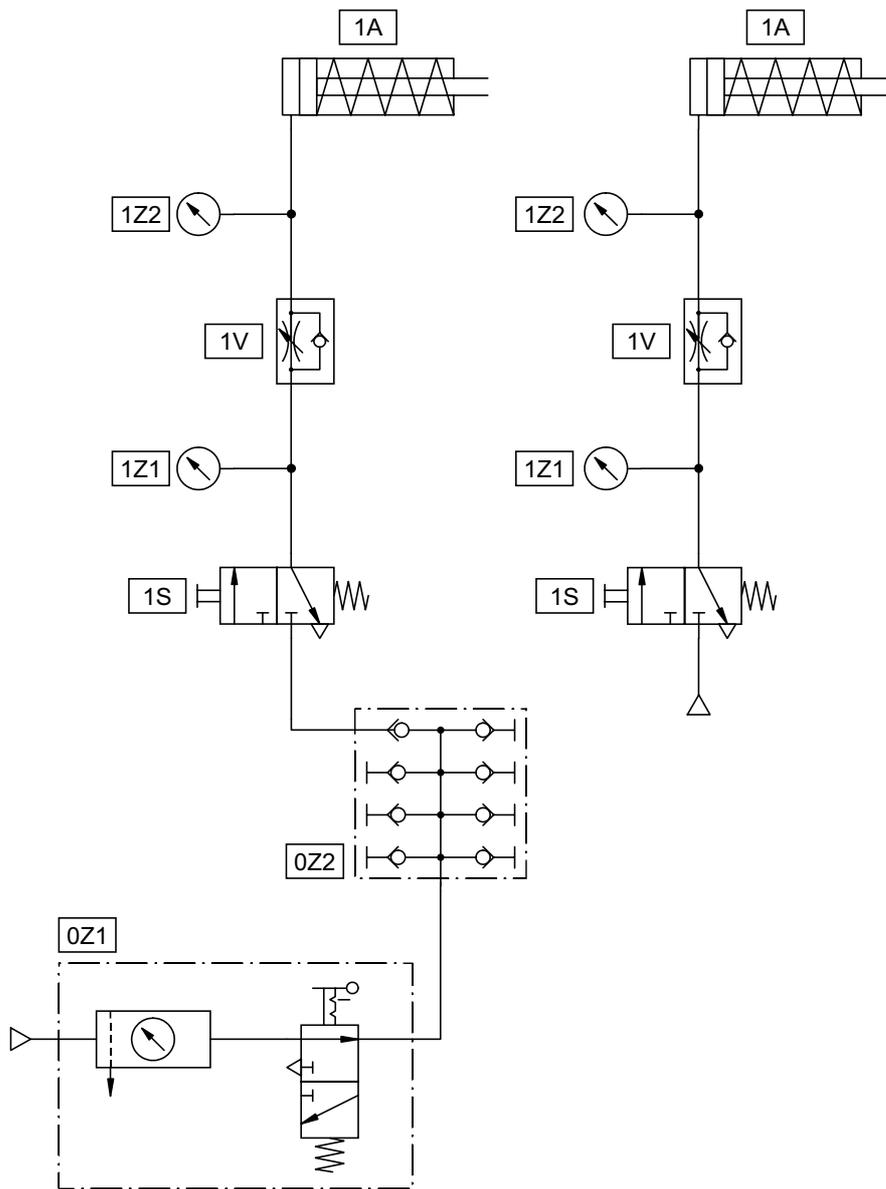
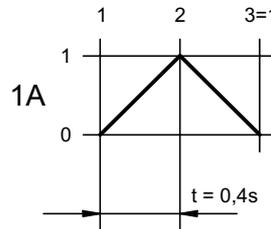


Fig. 2/2: Circuit diagram

a) Simplified representation of service unit with on-off valve

b) Representation without service unit with on-off valve and manifold

Fig. 2/3: Displacement-step diagram



Simplified representation without signal lines

Solution description

In the circuit diagram, a distinction is made between the simplified representation of the service unit with on-off valve and the version without service unit and on-off valve and manifold, (see also circuit diagram of exercise 1). The circuit diagrams of exercises 3 to 20 are shown without these components.

Initial position

In the initial position, the piston assumes the retracted end position. The volume of air inside the cylinder (1A) is evacuated via the 3/2-way push button valve (1S).

Step 1-2

By actuating the 3/2-way valve (1S), the chamber on the piston rod side of cylinder (1A) is pressurised via the one-way flow control valve (1V). The single-acting cylinder advances to its forward end position. The duration of the forward motion is set by means of the one-way flow control valve (stop watch). The flow control setting can be secured by means of the lock nut. The pressure gauge (1Z1) indicates the operating pressure during the forward motion and when the cylinder comes to rest in the advanced position. On the other hand, gauge (1Z2) shows pressure build-up during the advance. Furthermore, after completion of the forward motion, the pressure continues to rise until the operating pressure has been reached. If the push button valve (1S) continues to be actuated, the cylinder remains in the forward end position.

Step 2-3

After releasing the valve actuator (1S), the air in the cylinder is exhausted via the one-way flow control valve (1V) and the 3/2-way valve (1S). The cylinder returns to the retracted end position.

Marginal condition

If the push button of the 3/2-way valve (1S) is briefly pressed, the cylinder advances only part of the way and returns immediately.

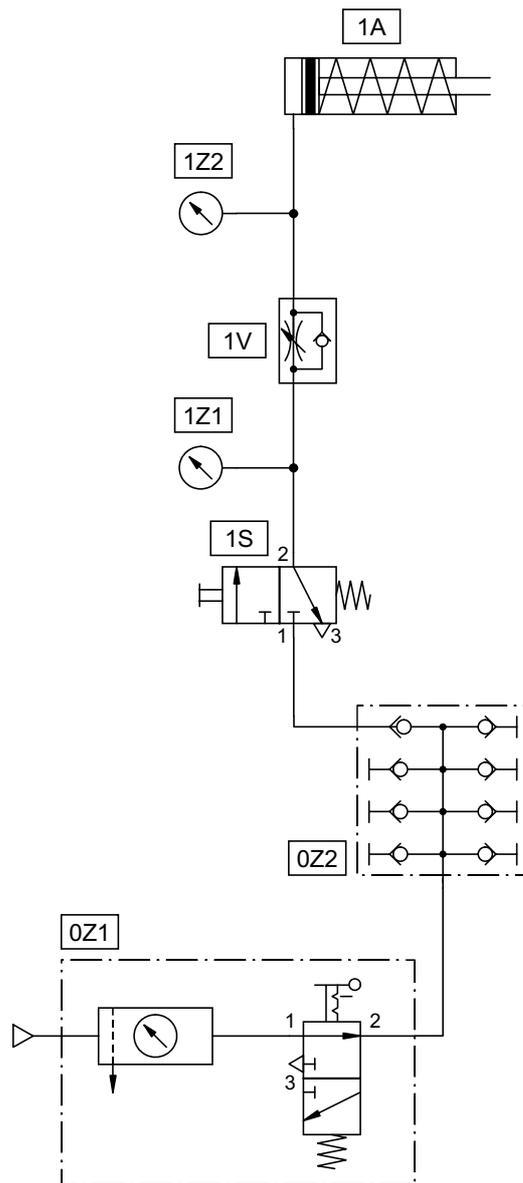


Fig. 2/4: Circuit design

C-10

Solution 2

<i>Components list</i>	<i>Components</i>	<i>Description</i>
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Single-acting cylinder
	1S	3/2-way valve with push button, normally closed
	1V	One-way flow control valve
	1Z1	Pressure gauge
	1Z2	Pressure gauge

- Follow up*
- Reverse the connections of the one-way flow control valve (1V). Observe the changed behaviour of the control system.
 - With single-acting cylinders, one distinguishes between supply air flow control (forward stroke) and exhaust air control (return stroke)
 - Exercise 9 gives an example of actuating a single-acting cylinder with supply and exhaust air control.

Separating parcel post

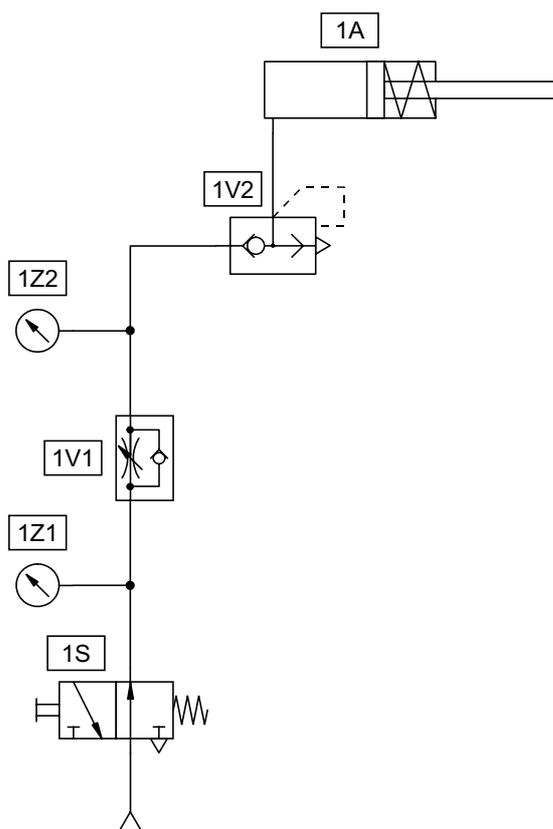
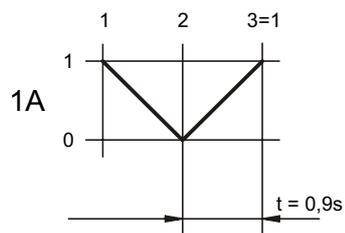


Fig. 3/2: Circuit diagram



Simplified representation without signal lines

Fig. 3/3: Displacement-step diagram

Solution description **Normal position**³

The installation is not pressurised. The piston rod of cylinder (1A) assumes the retracted end position through the action of the return spring.

Initial position

In the initial position, the single-acting cylinder is advanced. The piston chamber is pressurised via the 3/2-way, normally open, push button valve (1S).

Step 1-2

By actuating the 3/2-way push button valve (1S), the volume of air in cylinder (1A) is exhausted via the quick exhaust valve (1V2). The cylinder returns rapidly. If the push button (1S) continues to be actuated, the piston rod remains in the retracted end position. The next parcel slides into the parcel tray.

Step 2-3

If the valve actuator is then released, the piston rod advances and lifts the parcel. The desired time of advance $t = 0.9$ seconds is set by means of the one-way flow control valve (1V1) (stop watch).

Marginal condition

If the push button is pressed briefly, the cylinder retracts only part of the way.

³ Normal position

The term "normal position" applies to the state in which moving parts are unactuated and assume a certain position, for instance through spring force.

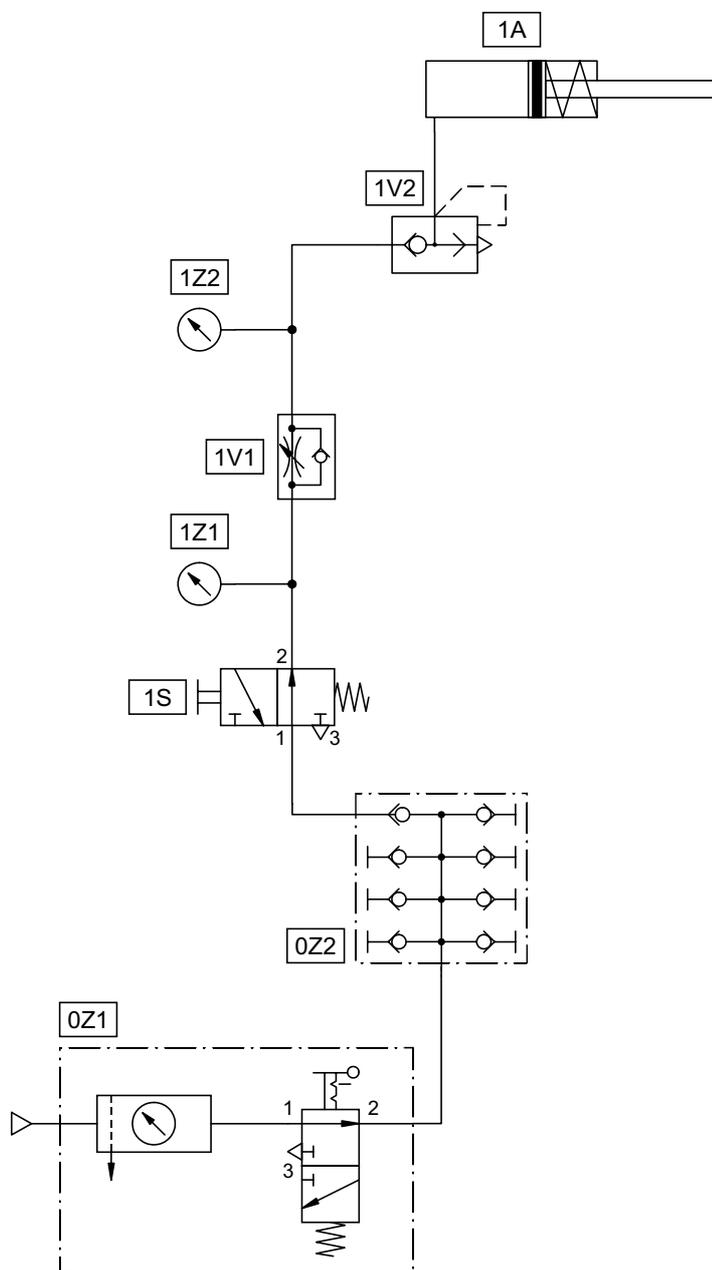


Fig. 3/4: Circuit design

The piece of tubing between the cylinder (1A) and the quick exhaust valve should be kept as short as possible. The shorter the piece of tubing, the more rapidly the piston rod will retract.



C-14

Solution 3

<i>Components list</i>	<i>Components</i>	<i>Description</i>
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Single-acting cylinder
	1S	3/2-way valve with push button, normally open
	1V1	One-way flow control valve
	1V2	Quick exhaust valve
	1Z1	Pressure gauge
	1Z1	Pressure gauge

Vertical switching point for briquettes

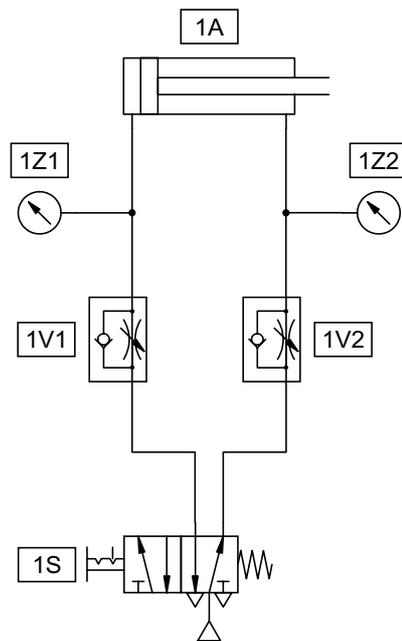
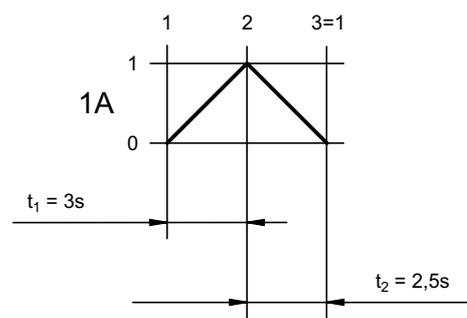


Fig. 4/2: Circuit diagram



Simplified representation without signal lines

Fig. 4/3: Displacement-step diagram

C-16

Solution 4

Solution description **Initial position**

In the initial position, the chamber on the piston rod side of the cylinder is supplied with air via 5/2-way valve (1S). The opposite side of the piston being exhausted. The cylinder is in the retracted end position. The pressure gauge (1Z2) indicates the operating pressure.

Step 1-2

If the selector switch of the 5/2-way valve (1S) with spring return is reversed, the cylinder (1A) travels slowly forward and remains in the advanced end position. The speed of advance is determined by the one-way flow control valve (1V2) on the piston rod side of the cylinder. The piston is held between two air cushions so that even very slow strokes are possible (exhaust air control). Observe the two pressure gauges (1Z1) and (1Z2).

Step 2-3

The selector switch (1S) is again reversed, which causes the cylinder to retract. The return stroke speed is determined by the one-way flow control valve (1V1).

Marginal condition

Reversing the selector switch (1S) during the forward or return stroke brings about immediate reversal of motion.

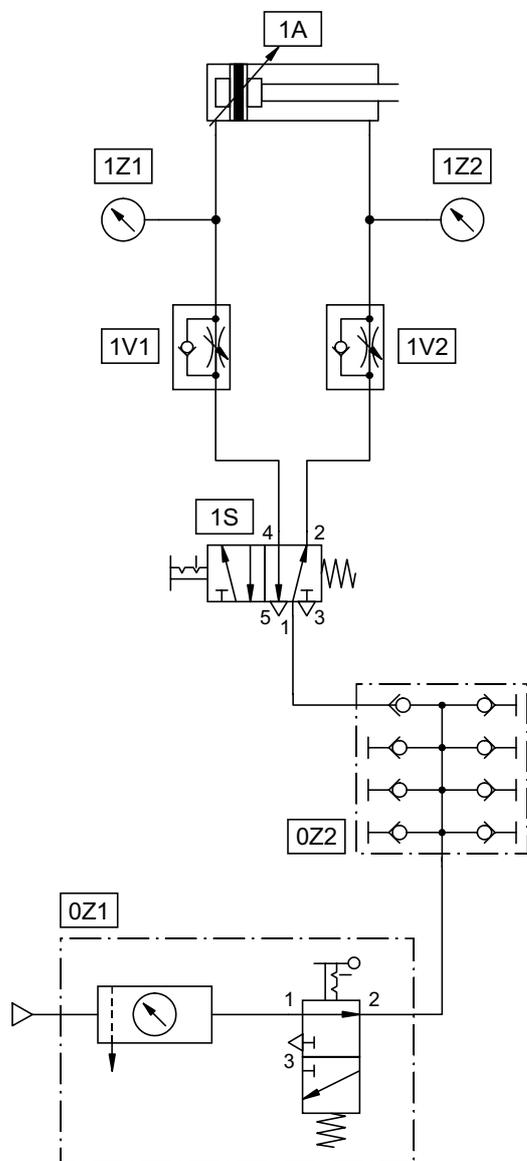


Fig. 4/4: Circuit design

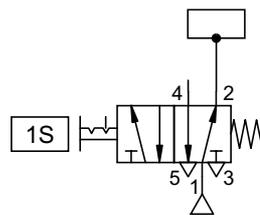
C-18

Solution 4

Components list	Components	Description
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Double-acting cylinder
	1Z1	Pressure gauge
	1Z2	Pressure gauge
	1V1	One-way flow control valve
	1V2	One-way flow control valve
	1S	5/2-way valve with selector switch

- Follow up*
- Reverse the connections of the two one-way flow control valves.. Observe the changed behaviour of the control system.
 - Replace the double-acting cylinder (1A) with a single-acting cylinder. Connect the cylinder to output 4(A) of the power valve. The output 2(B) of the 5/2-way valve (1S) with spring return and selector switch is closed. (Connect a T-piece (quick push-pull connector) to the valve via a short piece of tubing. Connect the remaining two outputs of the T-piece with another short piece of tubing).
 - Now interchange output 4(A) with 2(B). Observe the behaviour of the control system.

Fig 4/5: 5/2-way valve



Edge folding device

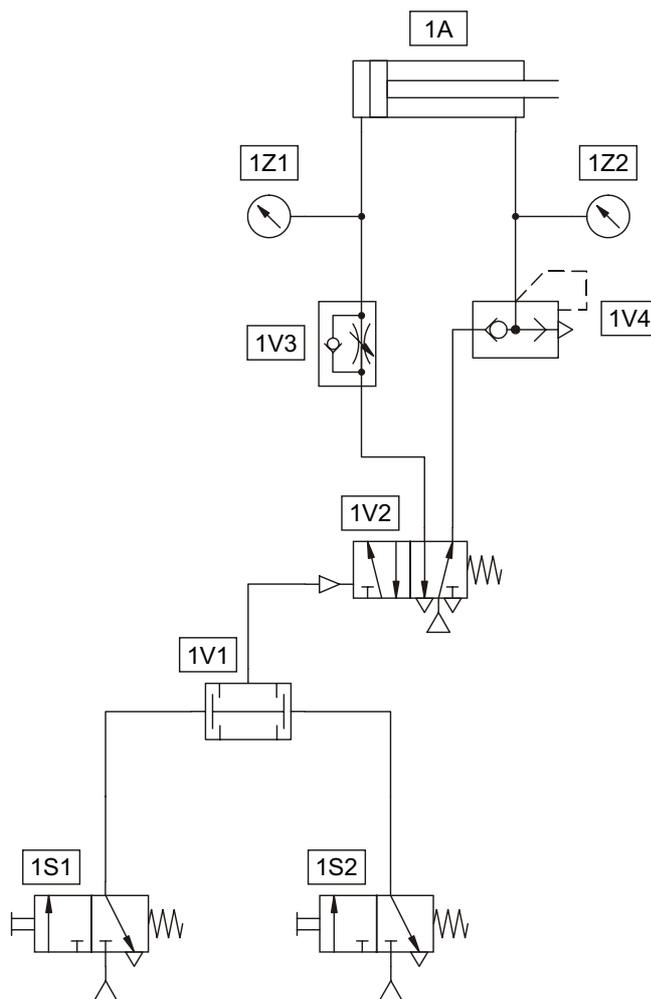
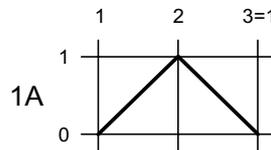


Fig. 5/2: Circuit diagram

The valve combination (1S1), (1S2) and (1V1) does not constitute a safety start-up function. It must not be put into practical use in this manner, the circuit must be assembled around a two-hand safety start unit.



Fig.5/3: Displacement-step diagram



Simplified representation without signal lines

Solution description **Initial position**

In the initial position, the piston rod of cylinder (1A) assumes the retracted end position. The power valve (1V2) is in the left hand switching position.

Step 1-2

If both 3/2-way valves (1S1) and (1S2) are actuated, pressure is applied at the output of the dual-pressure valve (1V1). The 5/2-way valve (1V2) reverses. The piston chamber of cylinder (1A) is supplied with unrestricted compressed air via the one-way flow control valve (1V3). The cylinder travels to its forward end position. As the chamber on the piston rod side is rapidly exhausted through the quick exhaust valve (1V4), the cylinder motion is very fast. If both 3/2-way valves (1S1) and (1S2) remain actuated, the cylinder remains in the forward end position.

Step 2-3

If at least one of the two push buttons (1S1) or (1S2) is released, power valve (1V2) is no longer pressurised. The valve reverses through the spring. The actuator travels to its initial position under conditions of flow restriction (1V3).

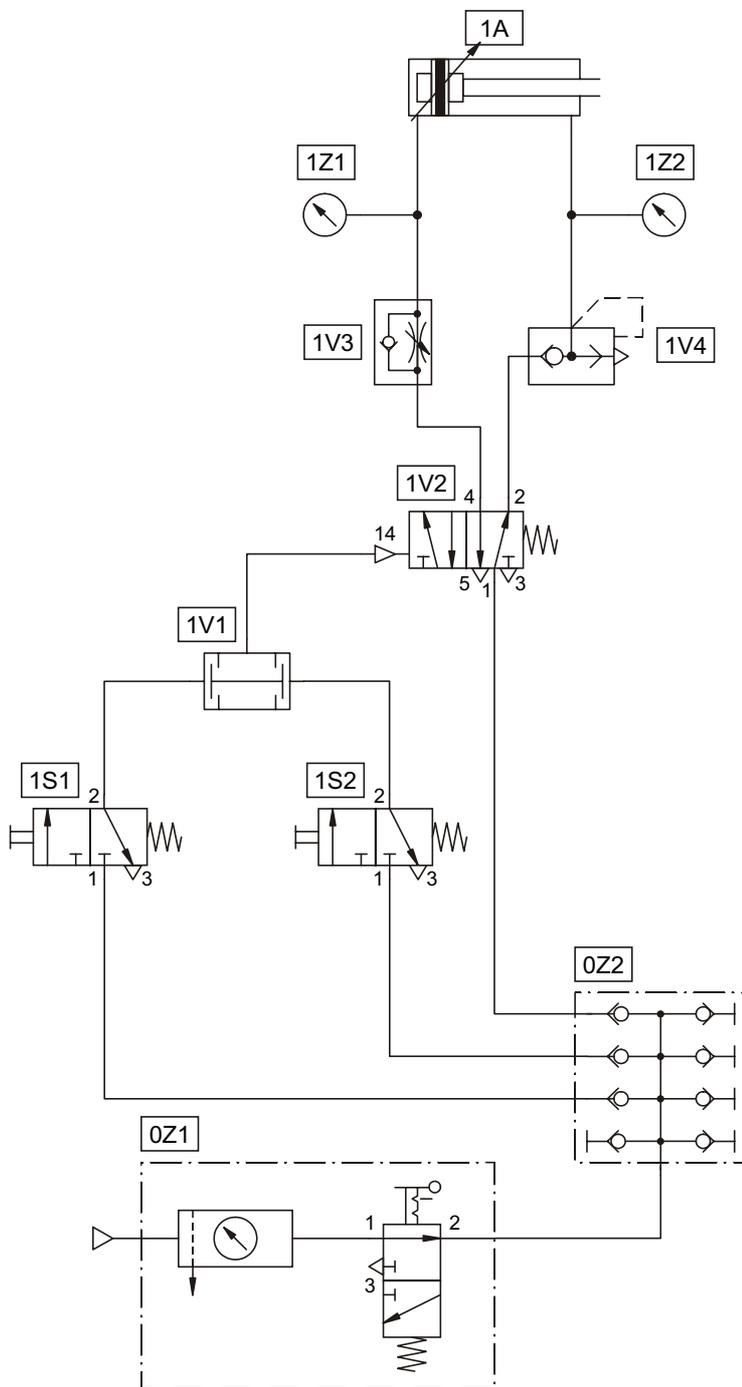


Fig. 5/4: Circuit design

C-22

Solution 5

<i>Components list</i>	<i>Components</i>	<i>Description</i>
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Double-acting cylinder
	1S1	3/2-way valve with push button, normally closed
	1S2	3/2-way valve with push button, normally closed
	1V1	Dual pressure valve
	1V2	5/2-way single pilot valve
	1V3	One-way flow control valve
	1V4	Quick exhaust valve
	1Z1	Pressure gauge
	1Z2	Pressure gauge

Follow up Device technology offers two ways of putting the logical AND function into practice.

- Remove the dual-pressure valve (1V1) from the control circuit and connect both 3/2-way valves (1S1) and (1S2) in series (input 1S1-1 to compressed air; output 1S1-2 to be piped to input 1S2-1; connect output 1S2-2 with input 1V2-14.)

Marking machine

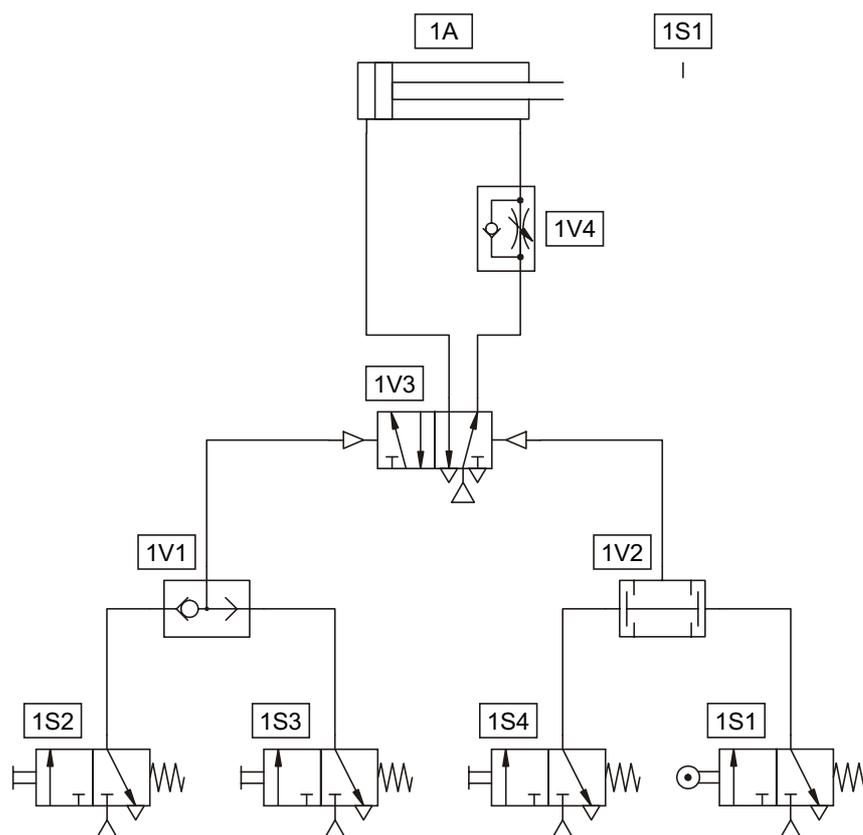


Fig. 6/2: Circuit diagram

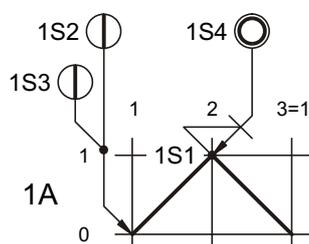


Fig. 6/3: Displacement-step diagram

Solution description **Initial position**

In the initial position, the piston rod of cylinder (1A) assumes the retracted end position. The pilot-operated 5/2-way bi-stable valve (1V1) with memory supplies air to the piston rod chamber and exhausts the chamber on the inlet side of the piston.

Step 1-2

If at least one of the two 3/2-way push button valves (1S2) and (1S3) is actuated, memory valve (1V3) reverses and the piston rod advances slowly with throttled exhaust air (1V4) – with this the surveyor's measuring rod is pushed forward. In the forward end position, the piston rod actuates the roller lever valve (1S1) by means of the trip cam. If no push button has been actuated, the cylinder remains in the forward end position.

Step 2-3

After pressing the push button of the directly actuated 3/2-way valve (1S3) for the return stroke, memory valve (1V3) reverses – the piston rod is rapidly retracted.

Marginal condition

The commencement of the return stroke through push button (1S4) can be initiated only when the forward end position has been reached and roller lever valve (1S1) thus actuated. If a counter signal is present at 5/2-way valve (1V3), the return stroke cannot be initiated.

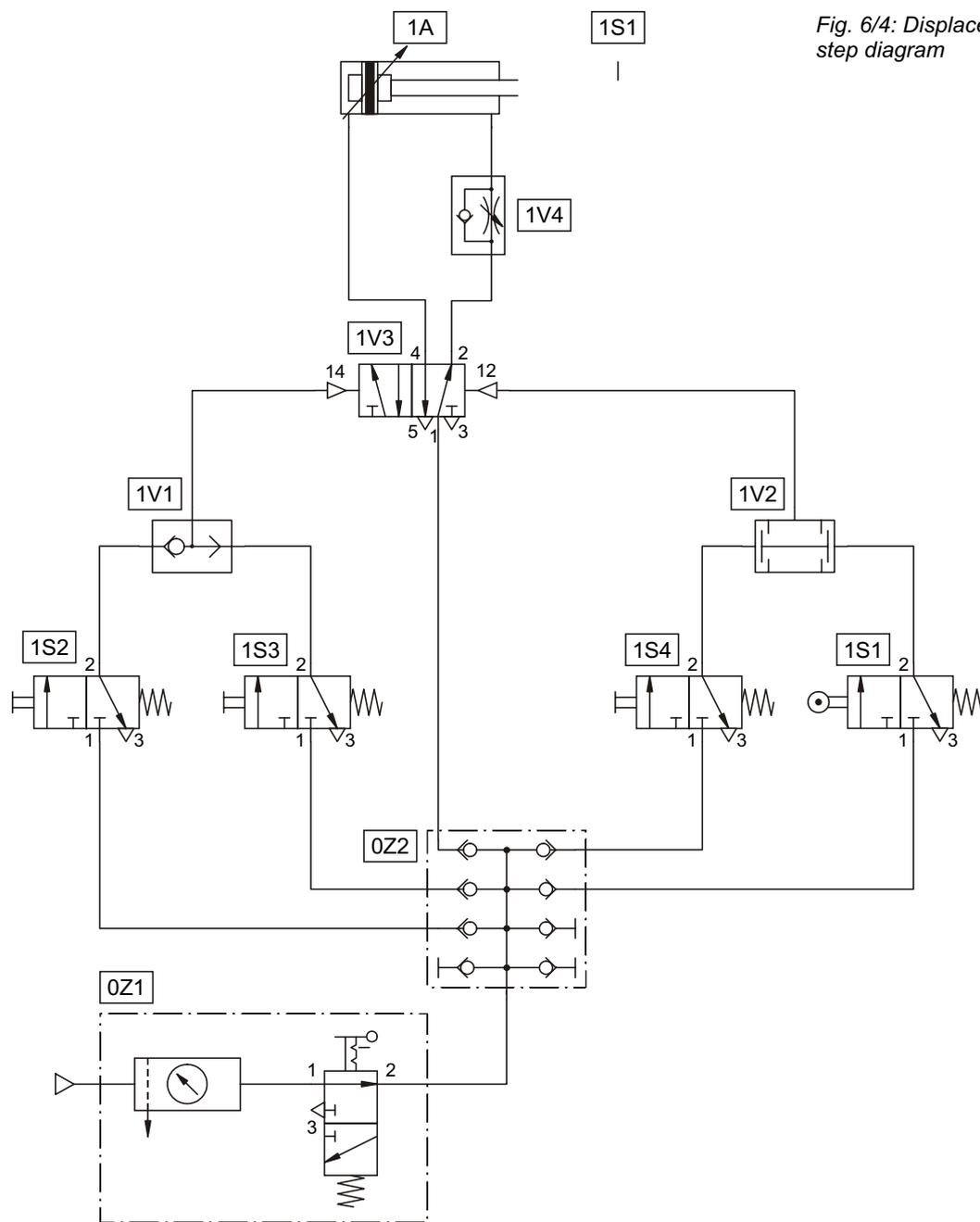


Fig. 6/4: Displacement-step diagram

C-26

Solution 6

<i>Components list</i>	<i>Components</i>	<i>Description</i>
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Double-acting cylinder
	1S1	3/2-way roller lever valve, normally closed
	1S2	3/2-way valve with push button, normally closed
	1S3	3/2-way valve with push button, normally closed
	1S4	3/2-way valve with push button, normally closed
	1V1	Shuttle valve
	1V2	Dual-pressure valve
	1V3	5/2-way double pilot valve
	1V4	One-way flow control valve

Separating out plain pins

Fig. 7/2: Circuit diagram

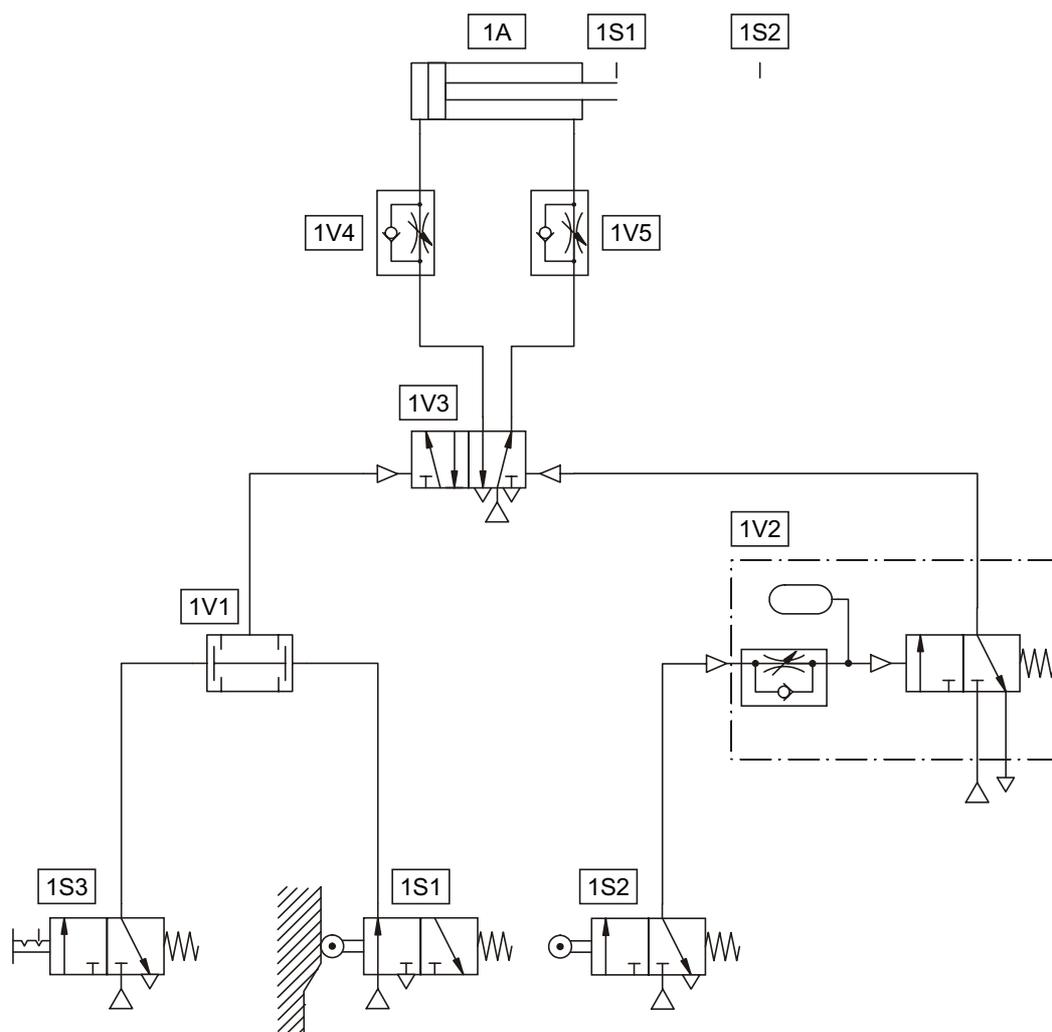
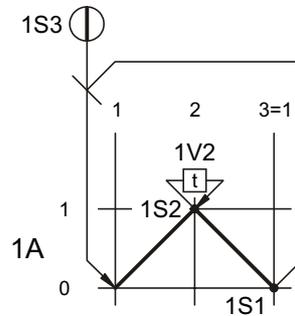


Fig. 7/3: Displacement-step diagram



Solution description **Initial position**

In the initial position the piston rod of the cylinder (1A) assumes the retracted position. The trip cam actuates the roller lever valve (1S1). One of the two start conditions is fulfilled.

Step 1-2

If the detented valve (1S3) is actuated, the second condition of the dual-pressure valve (1V1) is fulfilled, and the final control element (1V3) is switched through. The piston rod extends with exhaust air throttled (1V5). The duration of the advance stroke is $t_1 = 0.6$ seconds. In the forward end position, the trip cam actuates the roller lever valve (1S2). The time delay valve (1V2) is pressurised. The reservoir is filled via the restrictor. After the set time of $t_2 = 1.0$ seconds, the 3/2-way valve of the time delay valve is switched. A one signal is present at the output port. The final control element (1V3) returns to its initial position.

Step 2-3

Reversing of the memory valve (1V3) causes the piston rod to retract with exhaust air throttled. The duration of the return stroke of $t_3 = 0.4$ seconds is set by means of the one-way flow control valve (1V4). When the roller lever valve (1S1) is re-actuated, the return stroke is carried out.

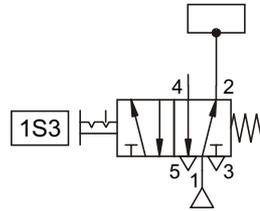
Continuous cycle

If the start valve (1S3) is depressed and remains in the actuated position, the piston rod carries out a continuous to and fro movement. Only when the detent (1S3) is returned to its initial position, is the motion sequence concluded at the end of the cycle.

C-30

Solution 7

Fig. 7/5: 5/2-way valve



Components list

Components	Description
0Z1	Service unit with on-off valve
0Z2	Manifold
1A	Double-acting cylinder
1S1	3/2-way roller lever valve, normally closed
1S2	3/2-way roller lever valve, normally closed
1S3	5/2-way valve with selector switch
1V1	Dual-pressure valve
1V2	Time delay valve, normally closed
1V3	5/2-way double pilot valve
1V4	One-way flow control valve
1V5	One-way flow control valve

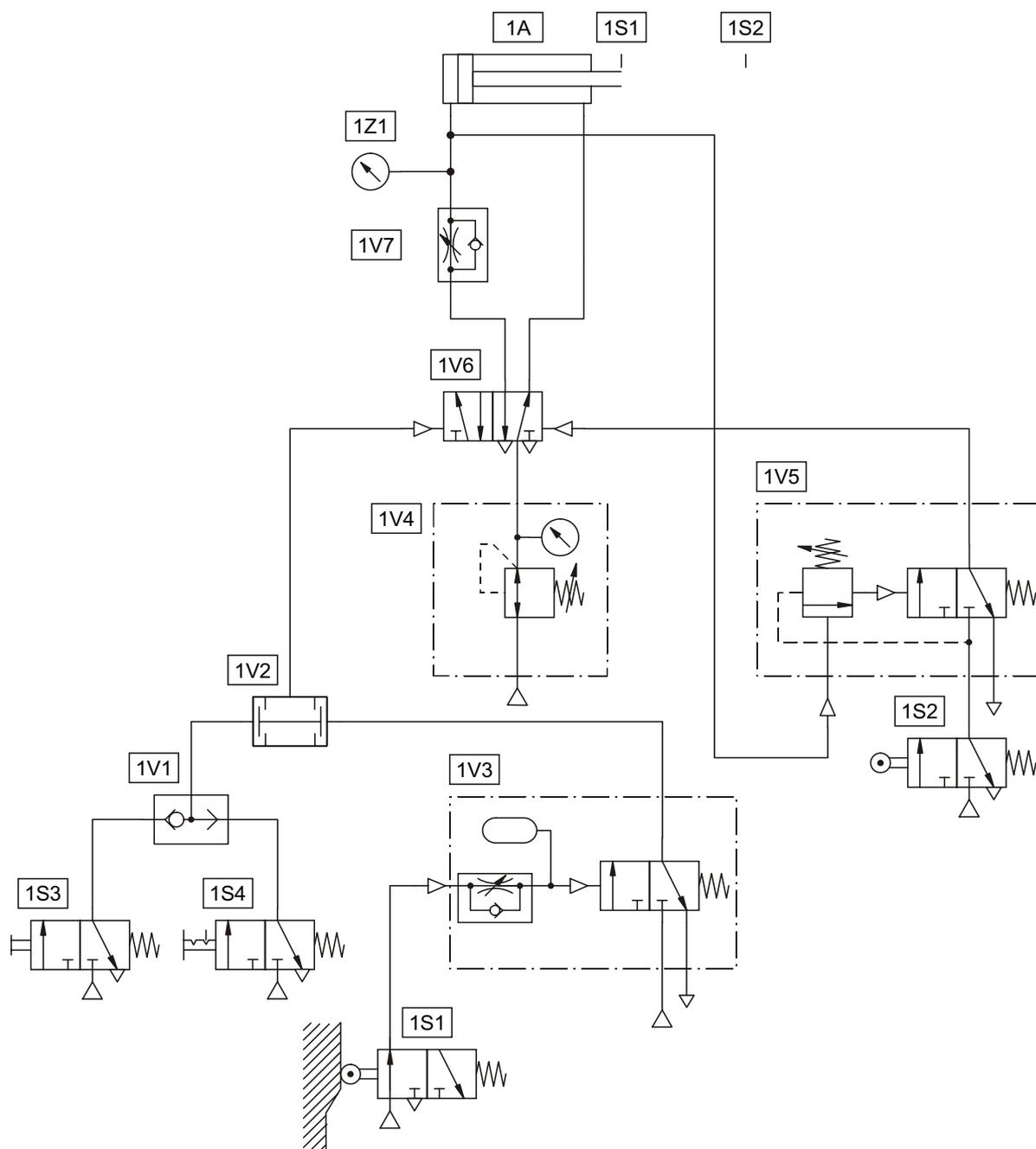
- Follow up*
- Mount the pressure sequence valve in the control in place of the time delay valve. Observe the behaviour of the control with a variety of settings.

The operating pressure for the service unit is set to $p = 6 \text{ bar}$ ($= 600 \text{ kPa}$).

- Lower the operating pressure in stages of $p = 1 \text{ bar}$ ($= 100 \text{ kPa}$). Determine the change in cycle time in relation to the operating pressure (stop watch).

Foil welding drum

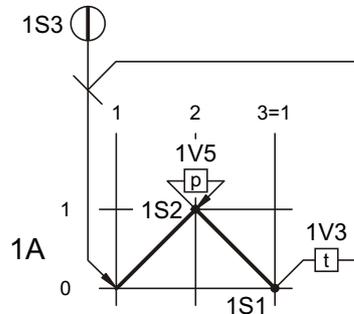
Fig. 8/2: Circuit diagram



The 3/2-way valve of the time delay valve (1V3) is actuated in the initial position.



Fig. 8/3: Displacement-step diagram



Solution description

Initial position

In the initial position, the cylinder assumes the retracted end position. The final control valve (1V6) supplies pressure to the chamber on the piston rod side of the cylinder. The roller lever valve (1S1) is depressed and the time delay valve (1V3) is actuated. A one-signal is present at the right-hand input of the dual-pressure valve (1V2).

Step 1-2

If the push button (1S3) is actuated, the shuttle valve (1V1) passes on a signal to the dual-pressure valve (1V2). This causes the reversal of the final control element (1V6). The cylinder extends slowly with supply air throttled (1V7). The pressure regulator (1V4) limits the pressure to a maximum of $p = 4 \text{ bar} (= 400 \text{ kPa})$. (The drum cannot be damaged by the rail). In the forward end position, the trip cam of the cylinder actuates the roller lever valve (1S2). This causes pressure to be applied to the pressure sequence valve (1V5) at input 1. The pressure sequence valve is actuated when a pressure of $p = 3 \text{ bar} (= 300 \text{ kPa})$ has been reached in the piston chamber. Adjust the flow control (1V7) so that the slow increase in pressure causes the cylinder to pause ($t_1 = 3 \text{ seconds}$) in the forward end position.

Step 2-3

Once the pressure sequence valve 1V5) has been switched, the final control element (1V6) is reversed. The cylinder travels to its initial start position. Re-actuation of the roller lever valve (1S1) causes power to be supplied to the pilot port of the time delay valve. Once the specified time of $t_2 = 2 \text{ seconds}$ has elapsed, the dual-pressure valve (1V2) is supplied with air to the right of the time delay valve (1V3) so that a renewed start is possible.

Continuous cycle

If the selector switch of the valve (1S4) is reversed, the control is switched to continuous cycle. Returning the detent to its initial position causes the control to stop at the end of the cycle.

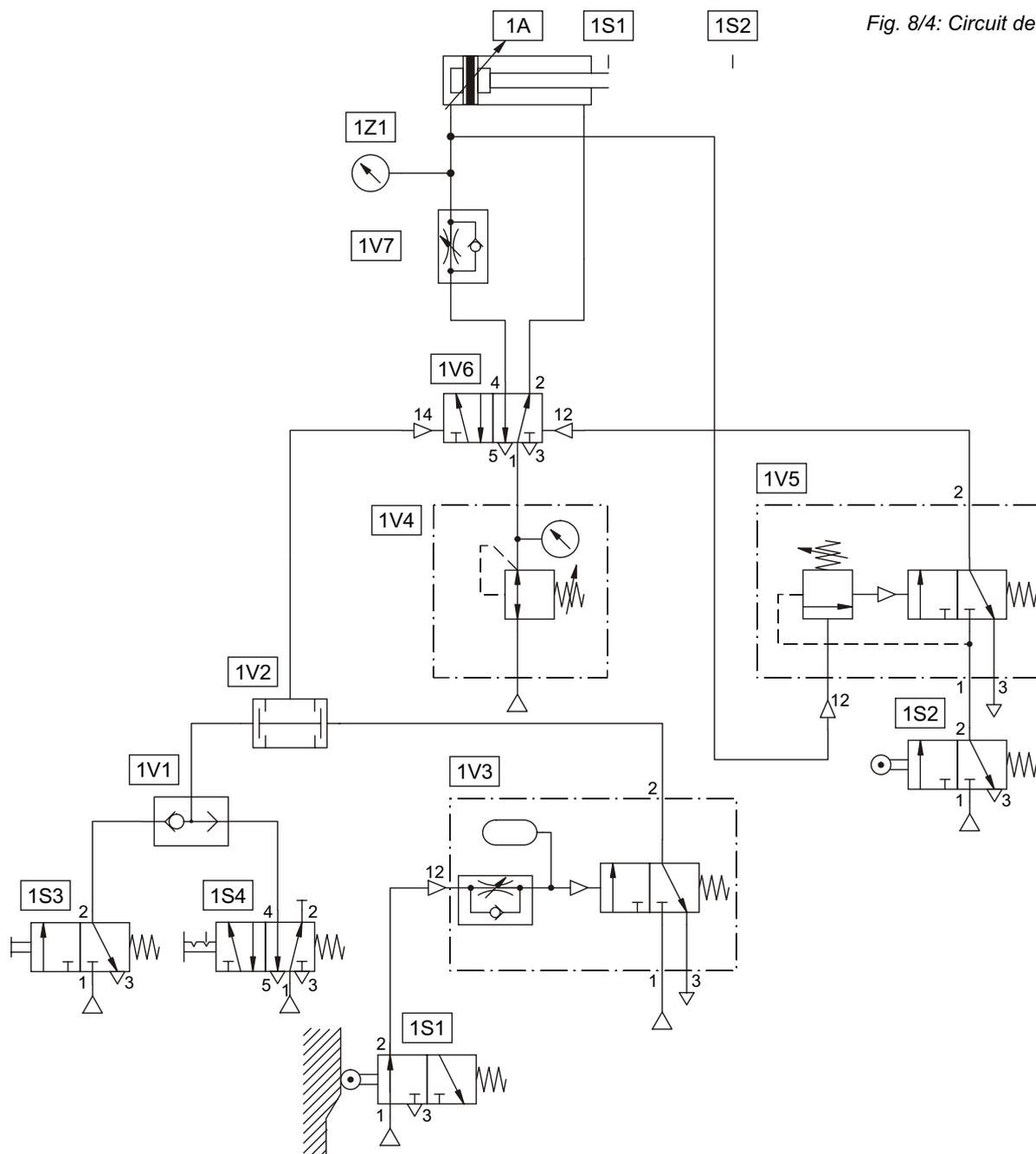


Fig. 8/4: Circuit design

The components – service unit with on-off valve (0Z1) and manifold (0Z2) are no longer shown in exercise 8 and from exercise 10 onwards..



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Solution 8

<i>Components list</i>	<i>Components</i>	<i>Description</i>
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Double-acting cylinder
	1S1	3/2-way roller lever valve, normally closed
	1S2	3/2-way roller lever valve, normally closed
	1S3	3/2-way valve with push button, normally closed
	1S4	5/2-way valve with selector switch
	1V1	Shuttle valve
	1V2	Dual-pressure valve
	1V3	Time delay valve, normally closed
	1V4	Pressure regulator with pressure gauge
	1V5	Pressure sequence valve
	1V6	5/2-way double pilot valve
	1V7	One-way flow control valve
	1Z1	Pressure gauge

Switching point for workpieces

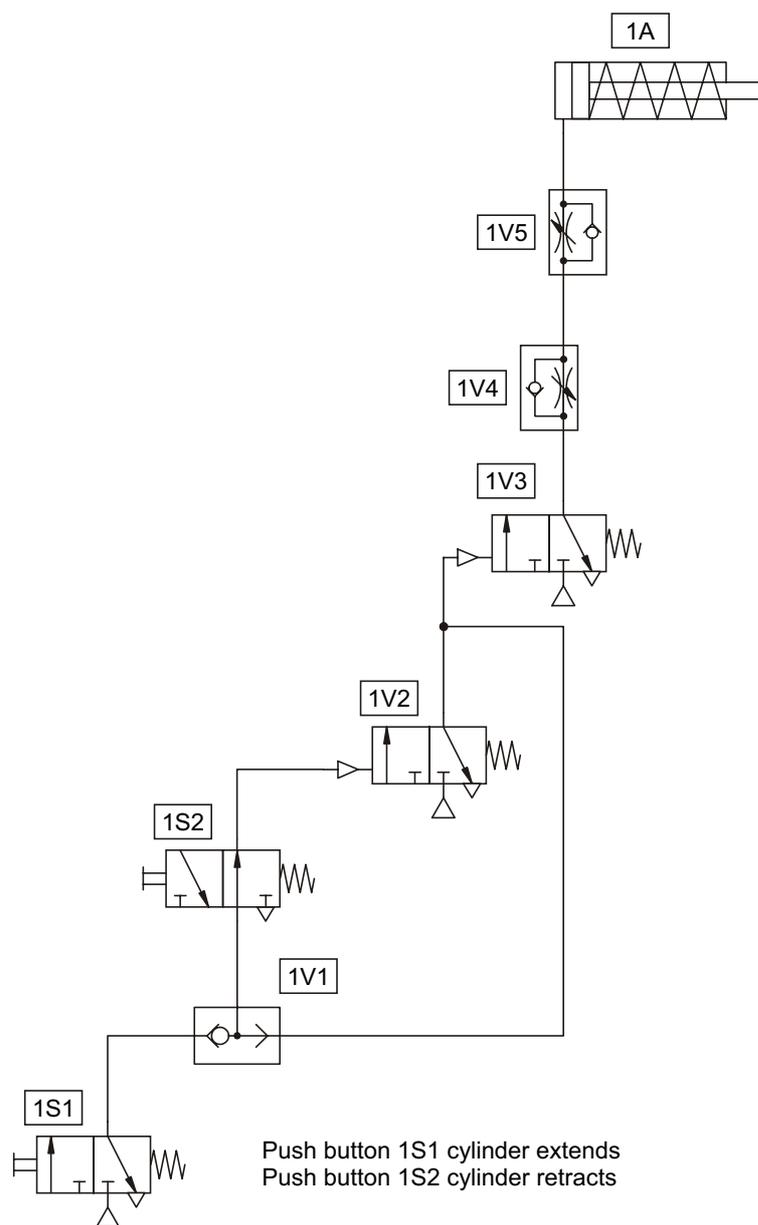
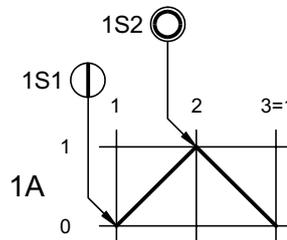


Fig. 9/2: Circuit diagram

Fig.9/3: Displacement-step diagram



Solution description **Self-latching circuit**

The group of valves (1S1), (1S2), (1V1) and (1V2) are arranged in a self-latching circuit. Actuation of a push button (1S1) causes a continuous on signal at the output of the valve (1V2). When the 3/2-way normally open valve (1S2) is actuated, the self-latching circuit is interrupted. A zero signal is present at the valve output (1V2). If both push buttons (1S1) and (1S2) are actuated, a zero signal is also present at the output (RS flip-flop behaviour with dominant off⁴).

Step 1-2

If the 3/2-way push button valve (1S1) is actuated, the single-acting cylinder (1A) is extended with flow control (1V5). The self-latching of the cylinder causes it to remain in the forward end position.

Step 2-3

After actuating the 3/2-way normally open valve (1S2), the cylinder retracts with flow control (1V4). The self-latching circuit is cancelled. The return spring causes the cylinder to remain in the retracted end position.

⁴ RS-flip-flop
R stands for reset
S stands for set

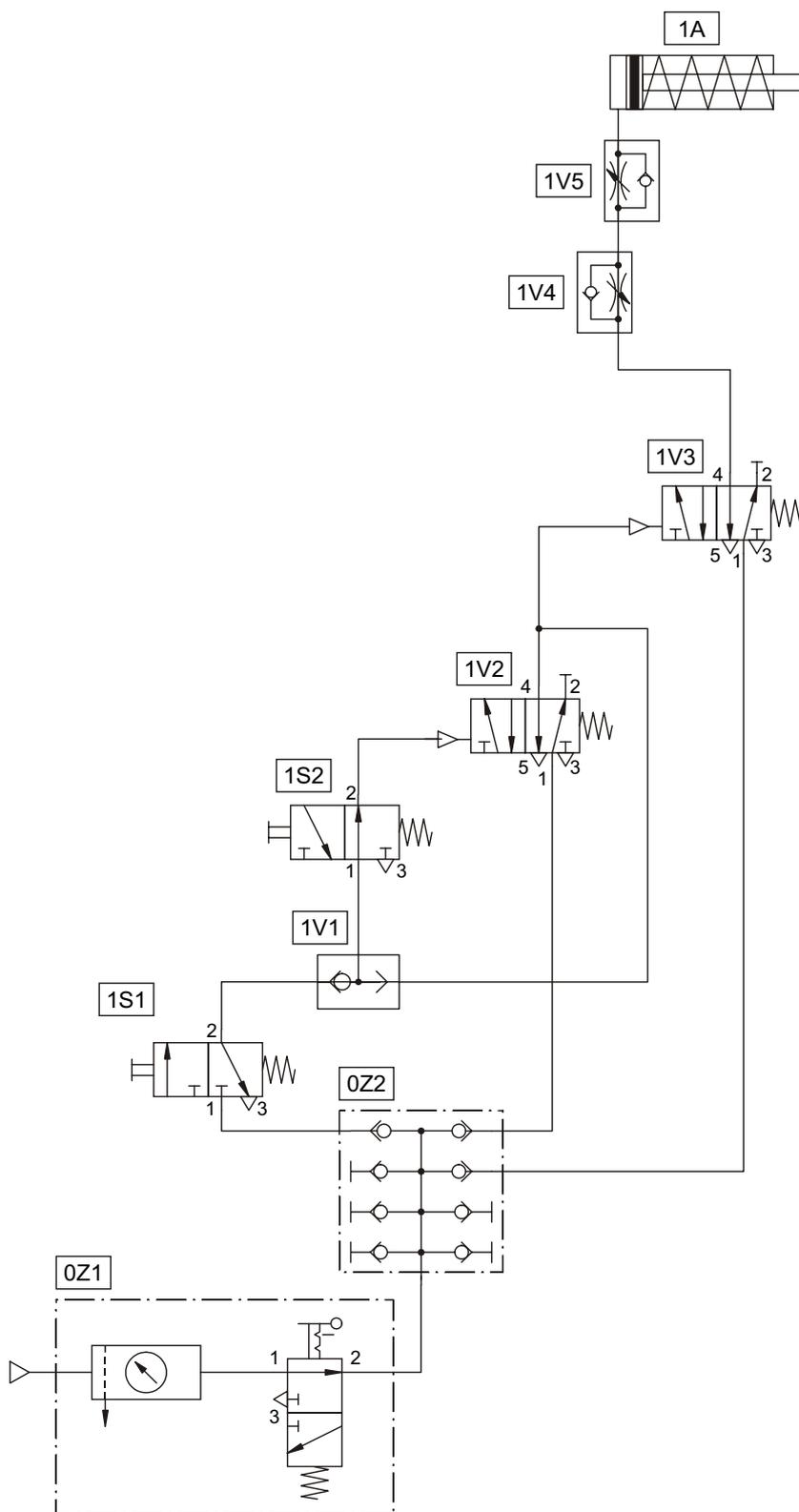


Fig. 9/4: Circuit design

<i>Components list</i>	<i>Components</i>	<i>Description</i>
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Single-acting cylinder
	1S1	3/2-way valve with push button, normally closed
	1S2	3/2-way valve with push button, normally open
	1V1	Shuttle valve
	1V2	5/2-way single pilot valve
	1V3	5/2-way single pilot valve
	1V4	One-way flow control valve
	1V5	One-way flow control valve

- Follow up*
- Remove the final control element (1V3) from the control system and connect the quick push-pull connector (T-connector) directly with the one-way flow control valve (1V4). The valve (1V2) is now not only a control element, but also assumes the function of the final control element. Set the one-way flow control valves (1V4) and (1V5) with the regulating screw to high flow.

Why do time delays now occur when setting and resetting the self-latching circuit?

- The pneumatic memory valve shown in the proposed solution is behaving as “dominant off”. Change the self-latching behaviour so that a “dominant on” function is caused.
- Replace the pneumatic memory valve (self-latching) by a mechanical memory valve (5/2-way pneumatic bi-stable valve)

How is it possible to distinguish between the behaviour of the circuit variants when switching on again after power failure?

Vibrator for paint buckets

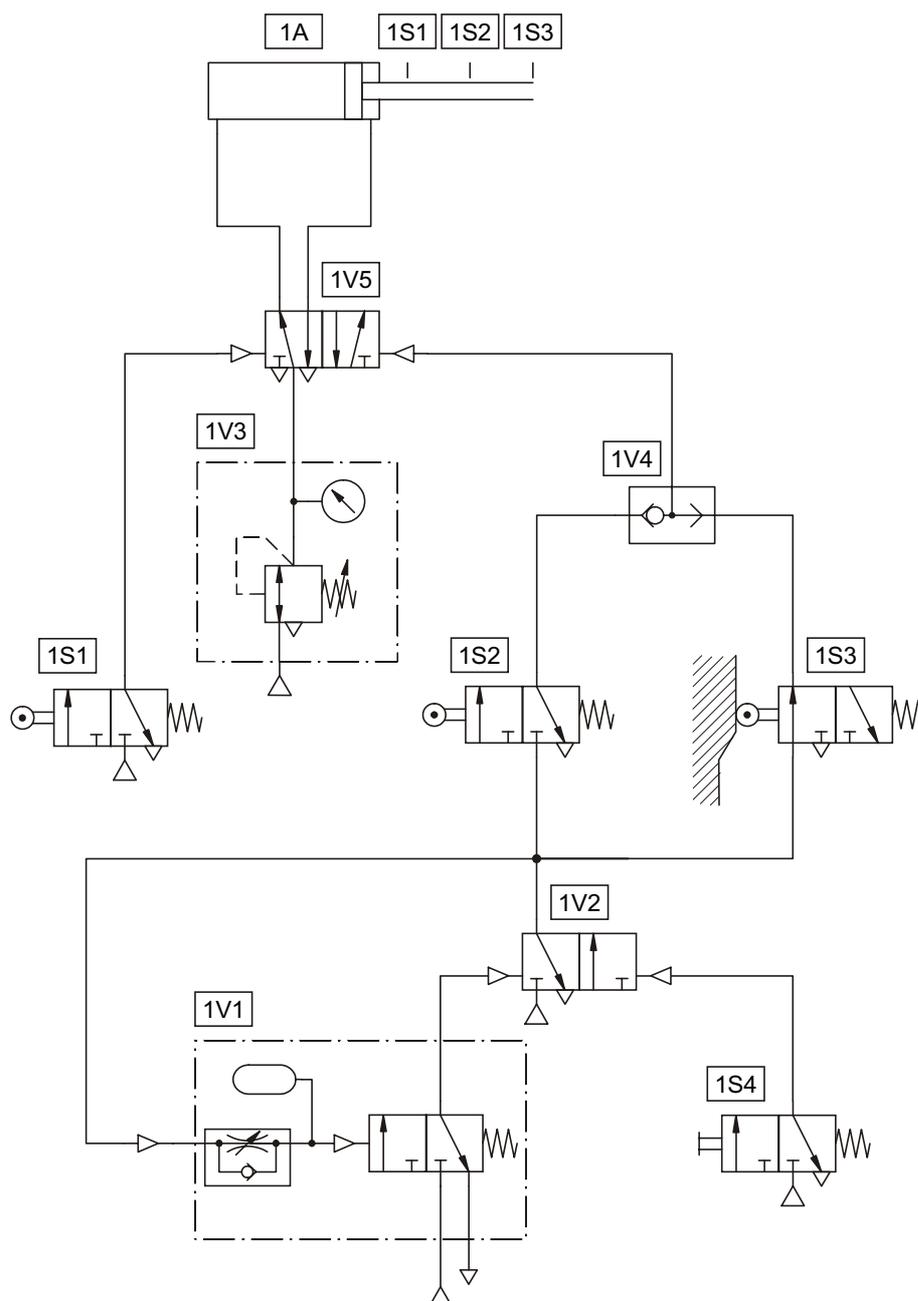
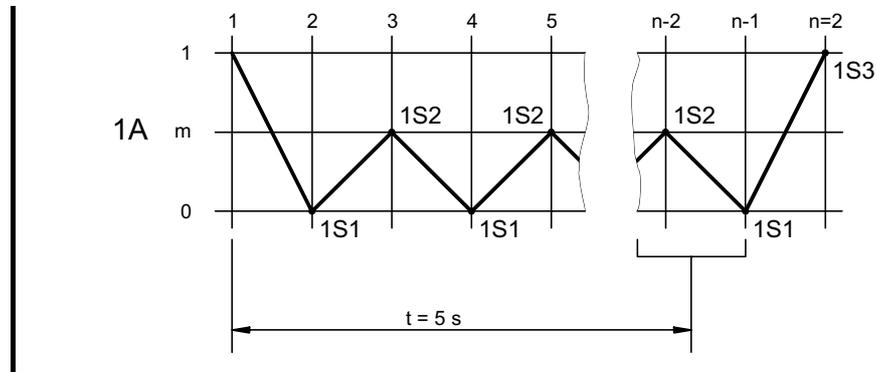


Fig. 10/2: Circuit diagram

Fig.10/3: Displacement-step diagram



Solution description **Initial position**

In the initial position, the cylinder assumes the forward end position and actuates the roller lever valve (1S3). The final control element (1V5) assumes the right-hand switching status. The memory valve (1V2) is also in the right-hand switching position.

Step 1-2

Actuating the push button (1S4) reverses the memory valve (1V2). Air is present at the pilot port of the time delay valve (1V1). The final control element (1V5) is reversed via the actuated roller lever valve (1S3) and the shuttle valve (1V4); the cylinder retracts. Travelling over the roller lever valve (1S2) does not yet have any effect. The trip cam actuates the roller lever valve (1S1) in the retracted end position.

Step 2-3

With the roller lever valve (1S1) actuated, the final control element (1V5) reverses. The cylinder partially extends and actuates the central roller lever valve (1S2).

Step 3-4

The cylinder is reversed again by actuation of the central roller lever valve (1S2). The reversing procedure for the valves (1S2), (1V4) and (1V5) lasts only a few milliseconds so that the trip cam does not travel over the roller lever valve (1S2).

Step 4-5

See step 2-3.

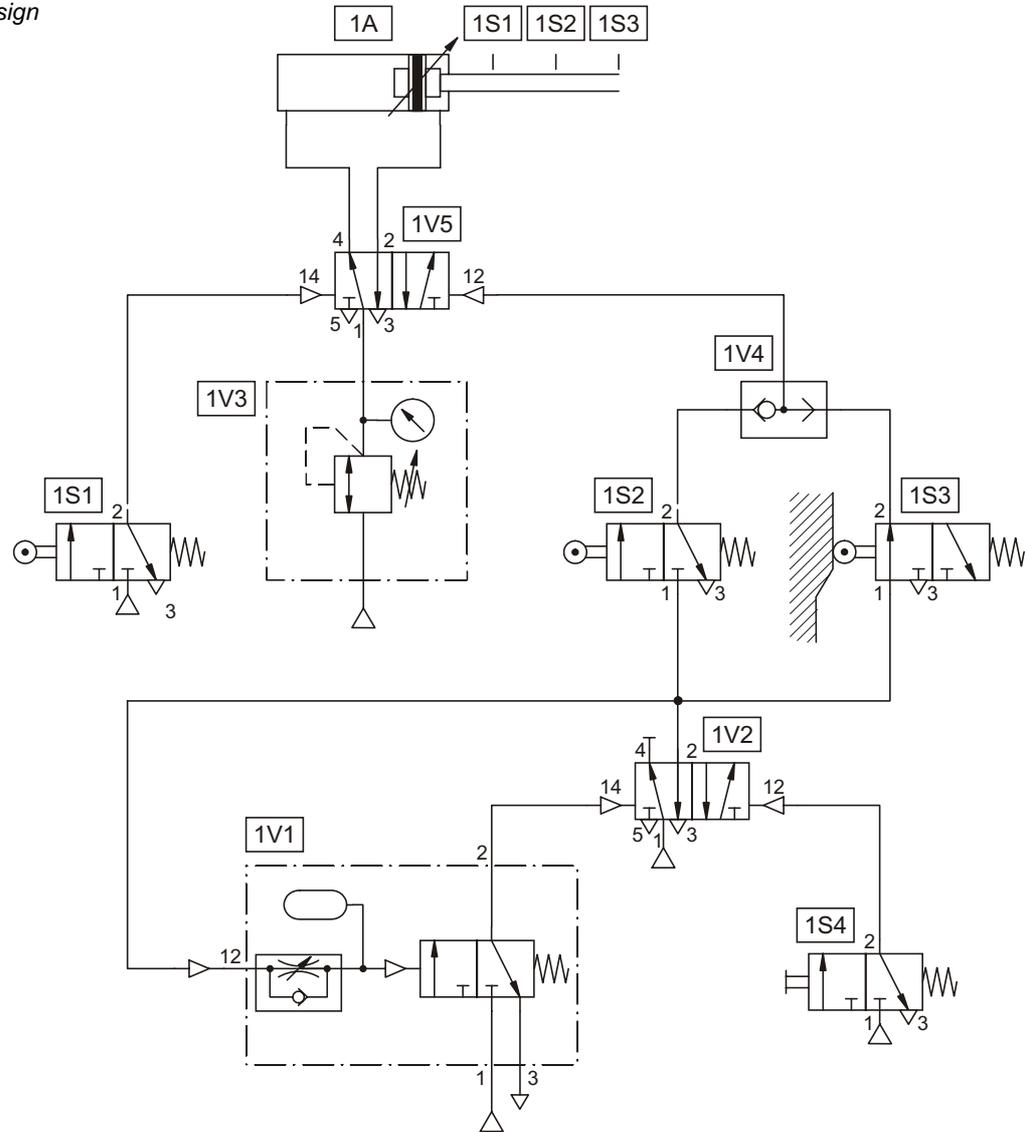
Oscillating movement

The cylinder oscillates backwards and forwards between the roller lever valves (1S1) and (1S2) until the specified time of $t = 5$ seconds has expired.

Steps n-2 to n

After the time delay valve (1V1) has been switched, the memory valve (1V2) is reversed. Roller lever valves (1S2) and (1S3) are no longer supplied with compressed air. The cylinder travels to the initial position (forward end position).

Fig. 10/4: Circuit design



The components – service unit with on-off valve (OZ1) and manifold (OZ2) are no longer shown from exercise 10 onwards.

<i>Components</i>	<i>Description</i>	<i>Components list</i>
0Z1	Service unit with on-off valve	
0Z2	Manifold	
1A	Double-acting cylinder	
1S1	3/2-way roller lever valve, normally closed	
1S2	3/2-way roller lever valve, normally closed	
1S3	3/2-way roller lever valve, normally closed	
1S4	3/2-way with push button, normally closed	
1V1	Time delay valve, normally closed	
1V2	5/2-way double pilot valve	
1V3	Pressure regulator with pressure gauge	
1V4	Shuttle valve	
1V5	5/2-way double pilot valve	

- Vary the quantity of air in the power valve (1V5) using the pressure regulator (1V3). Observe the behaviour of the actuator. *Follow up*

C-44

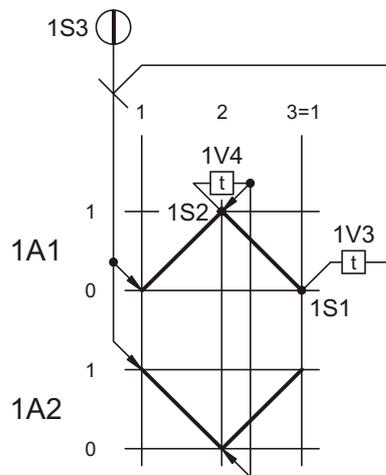
Solution 10



Only one time delay valve is contained in the set of equipment for the basic course. The second time delay valve (1V4) can be improvised by using a one-way flow control valve and a piece of tubing of about 1 m length (see circuit design).

The 3/2-way valve of the time delay valve (1V3) is actuated in the initial position.

Fig. 11/3: Displacement-step diagram



Solution description **Latching**

In the group of valves (1S3), (1S4), (1V1) and (1V2), we have a latching circuit with “dominant off response” (RS flip flop behaviour with dominant off). If the valve with selector switch (1S4) is reversed, operation of the push button (1S3) provides a constant one-signal at the output of the valve (1V2). Resetting valve (1S4) interrupts the latching. The system will not restart on its own when compressed air is restored after a power failure.

Initial position

In the initial position, cylinder (1A1) is retracted and cylinder (1A2) advanced. The roller lever valve (1S1) is actuated. A one-signal is present at the output of time delay valve (1V3).

Step 1-2

After actuation of start button (1S3), valve (1V2) reverses. As pressure is applied to the right and left-hand side of the dual pressure valve (1V5), it switches through and the final control component (1V6) is reversed. The two cylinders move towards opposed end positions. Two spark plug blanks are fed to the machining device. Through actuation of the roller lever valve (1S2), time delay valve (1V4) receives a one-signal at the pilot port. The air reservoir is filled via the adjustable flow control valve. Filling time is to amount to $t_1 = 1$ second.

Step 2-3

When the reservoir of the time delay valve (1V4) has reached the switching pressure of $p = 3$ bar (= 300 kPa), the 3/2-way valve of the time delay valve switches through. The final control element (1V6) is then reversed. The two cylinders move into opposing end positions. Gravity causes a pair of spark plug blanks to roll out. Time delay valve (1V3) receives a one-signal at the pilot port through the actuated roller lever valve (1S1). After the set time of $t_2 = 2$ seconds, the dual pressure valve (1V5) receives a signal at the right-hand side and in this way a renewed start is possible.

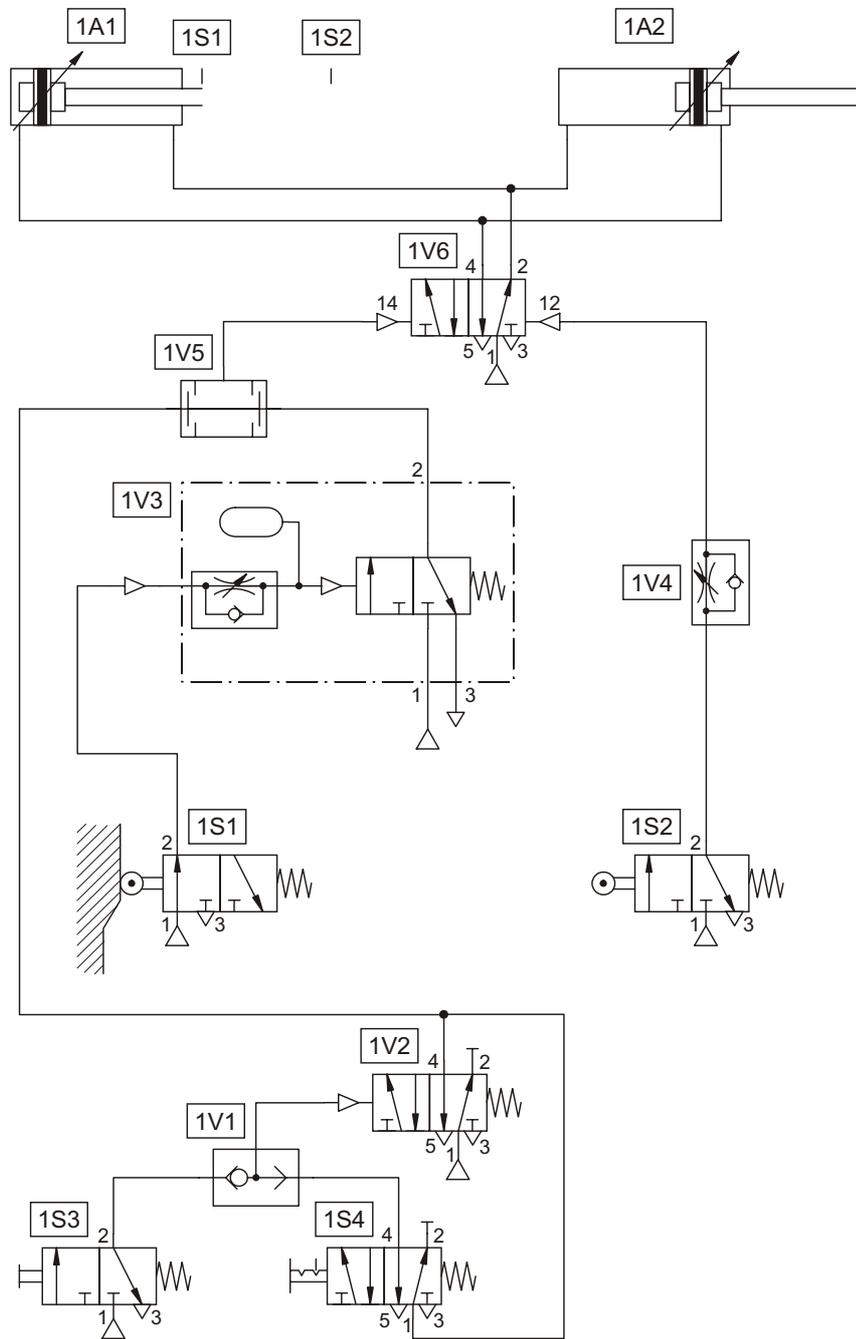
Continuous cycle

If the valve with selector switch (1S4) is switched and start button (1S3) operated, the control system runs in continuous cycle. Reversing the valve with selector switch into the initial position stops the sequence at the end of a cycle.

C-48

Solution 11

Fig. 11/4: Circuit design



The one-way flow control valve (1V4) and a piece of tubing of about 1 m length to the final control element have the same effect as a time delay valve (see circuit diagram 1V3). However, please observe this gives rise to a creeping signal.



The components – service unit with on-off valve (0Z1) and manifold (0Z2) are no longer shown.

Components	Description
0Z1	Service unit with on-off valve
0Z2	Manifold
1A1	Double-acting cylinder
1A2	Double-acting cylinder
1S1	3/2-way roller lever valve, normally closed
1S2	3/2-way roller lever valve, normally closed
1S3	3/2-way valve with push button, normally closed
1S4	5/2-way valve with selector switch
1V1	Shuttle valve
1V2	5/2-way single pilot valve
1V3	Time delay valve, normally closed
1V4	One-way flow control valve
1V5	Dual-pressure valve
1V6	5/2-way double pilot valve

Components list

Through final control valve (1V6), the cylinders are supplied with compressed air. Switch the pressure regulator to input 1 of the final control element.

Follow up

- Lower the operating pressure in steps of $p = 1 \text{ bar}$ ($= 100 \text{ kPa}$). Observe the changed advancing and returning of the cylinders.

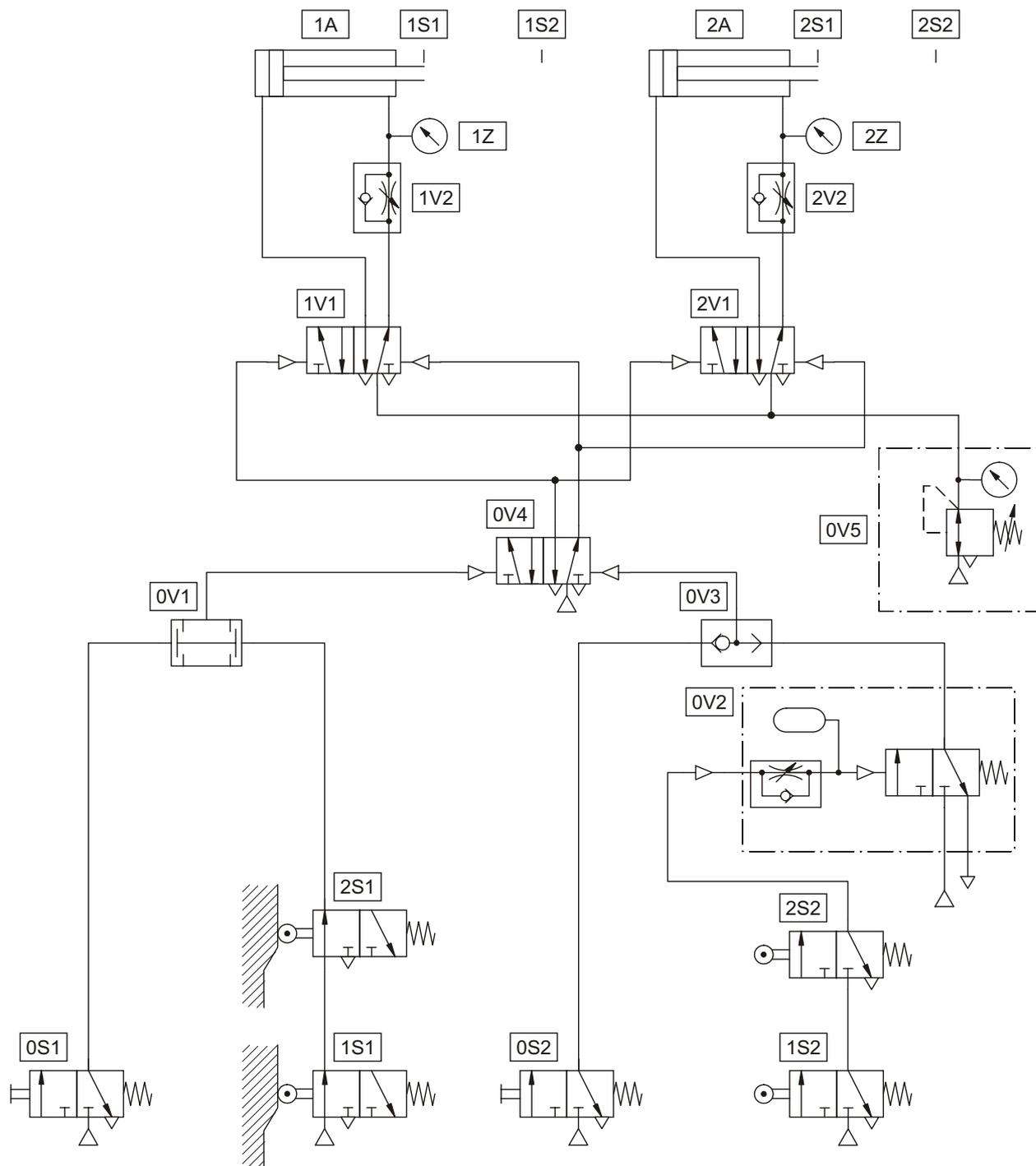
As the frictional forces of two cylinders are generally different, parallel running of the cylinders can be achieved to a limited extent only (see also exercises 12 and 13).

C-50

Solution 11

Welding machine for thermoplastics

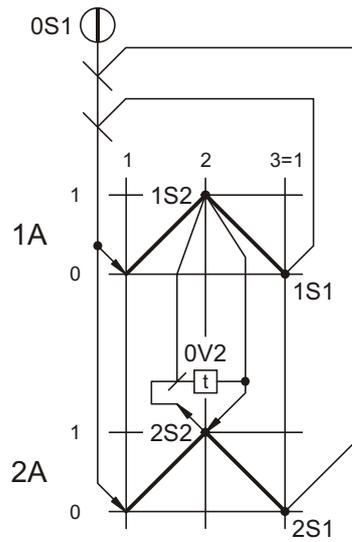
Fig. 12/2: Circuit diagram





There are three roller lever valves in the set of equipment of "Basic level TP101". For building the circuit shown, four roller lever valves are needed. As an expedient, roller lever valve (2S2), for example, could be omitted..

Fig. 12/3: Displacement-step diagram



Initial position

In the initial position, both cylinders (1A) and (2A) assume the retracted end position. The roller lever valves (1S1) and (2S1) are actuated. Final control elements (1V1) and (2V1) and directional control valve (0V4) are in the left-hand switching position.

Solution description

Step 1-2

When push button (0S1) is operated, first directional control valve (0V4) and then final control elements (1V1) and (2V1) are reversed. Both cylinders advance with their exhaust air restricted. In the forward end position, roller lever valves (1S2) and (2S2) are actuated. The cylinders remain in the forward end position. The pilot port of time delay valve (0V2) is pressurised via the two roller lever valves (1S2) and (2S2). The valve is required to switch when a time lag of $t=1.5$ seconds has elapsed.

Step 2-3

After the time delay valve (0V2) has switched through, the three identical 5/2-way double pilot (bi-stable) valves reverse. The cylinders move into the retracted position and there again actuate the roller lever valves (1S1) and (2S1).

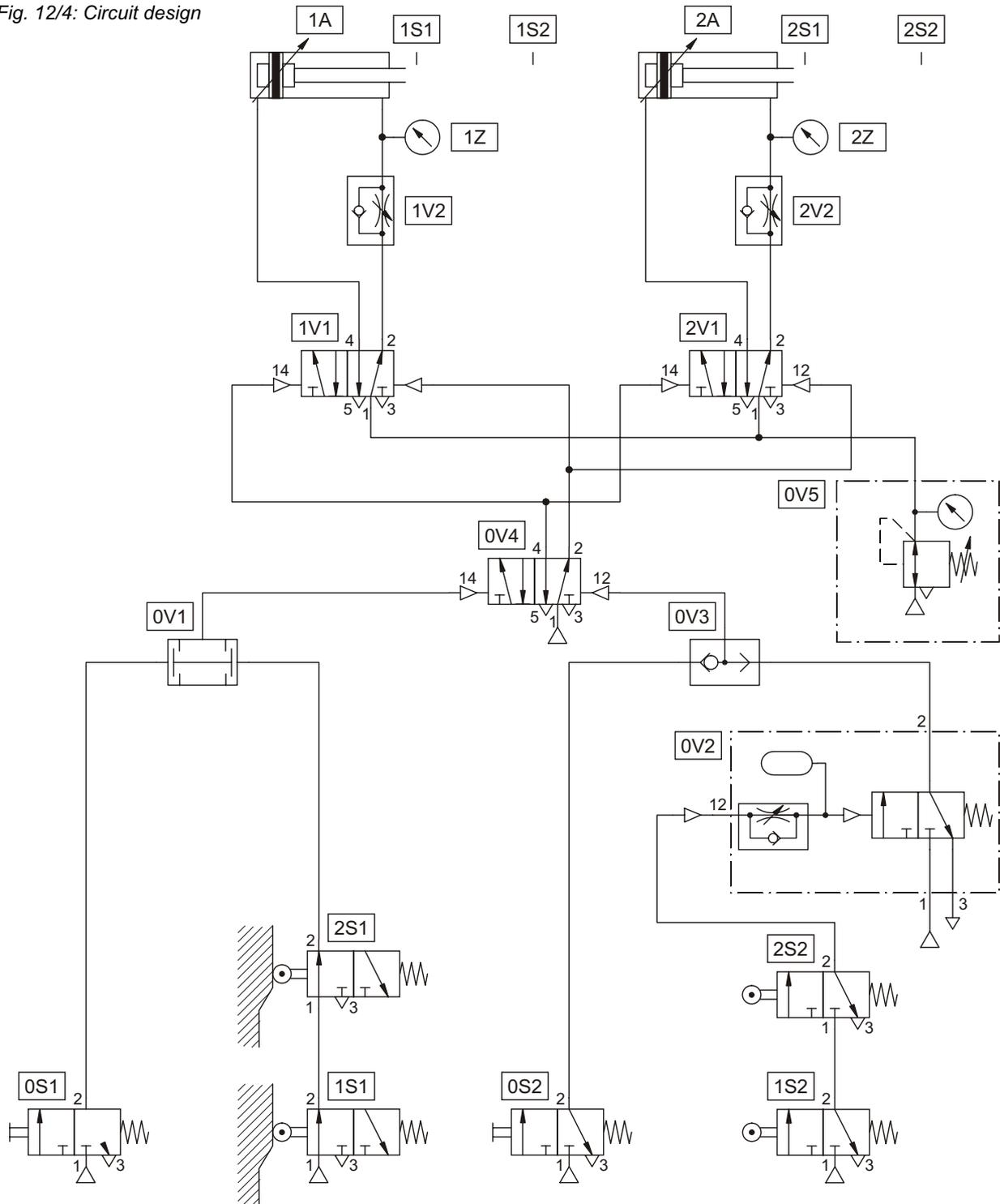
Push button (0S2)

If 3/2-way valve (0S2) is operated, the three identical 5/2-way double pilot (bi-stable) valves (1V1), (2V1) and (0V4) are reversed; the cylinders return to the retracted end position.

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Solution 12

Fig. 12/4: Circuit design



There are 3 roller lever valves in the set of equipment for "Basic level TP101". To build to the circuit diagram shown, you need four roller lever valves. As an expedient, roller lever valve (2S2), for example, may be omitted.



The components – service unit with on-off valve (0Z1) and manifold (0Z2) are no longer shown..

Components	Description
0S1	3/2-way valve with push button, normally closed
0S2	3/2-way valve with push button, normally closed
0V1	Dual pressure valve
0V2	Time delay valve, normally closed
0V3	Shuttle valve
0V4	5/2-way double-pilot valve
0V5	Pressure regulator with pressure gauge
0Z1	Service unit with on-off valve
0Z2	Manifold
1A	Double-acting cylinder
1S1	3/2-way roller lever valve, normally closed
1S2	3/2-way roller lever valve, normally closed
1V1	5/2-way double pilot valve
1V2	One-way flow control valve
1Z	Pressure gauge
2A	Double-acting cylinder
2S1	3/2-way roller lever valve, normally closed
2S2	3/2-way roller lever valve, normally closed
2V1	5/2-way double pilot valve
2V2	One-way flow control valve
2Z	Pressure gauge

Components list

- Reduce the pressure from the pressure regulator (0V5) in steps of $p = 1 \text{ bar} (= 100 \text{ kPa})$. Observe the behaviour of the cylinders and the readings on the pressure gauges.
- Regarding the note on the opposite page: Replace the fourth roller lever valve (2S2) by a roller lever valve with idle return. Investigate the behaviour of the control system with different settings of one-way flow control valves (1V2) and (2V2).

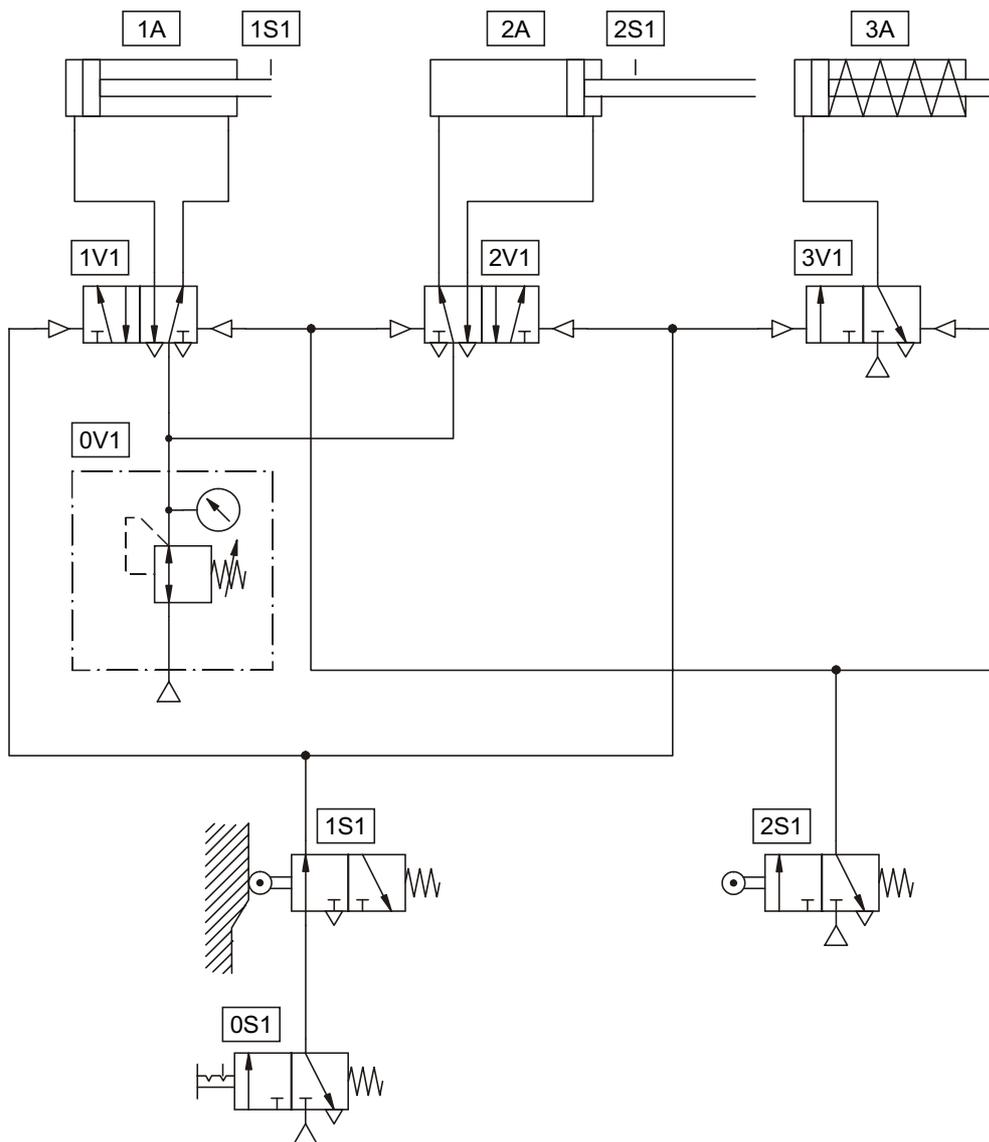
Follow up

C-56

Solution 12

Quarry stone sorter

Fig. 13/3: Circuit diagram



<i>Abbreviated notation</i>	1A+	1A-
	2A-	2A+
	3A+	3A-

Solution description **Initial position**

In the initial position, double acting cylinder (1A) – upper sieve – and single-acting cylinder (3A) – unclogger – assume the retracted end position; the double-acting cylinder (2A) – lower sieve – rests in the forward end position. Roller lever valve (1S1) is actuated.

Step 1-2

After operation of the valve with selector switch (0S1) final control elements (1V1), (2V1) and (3V1) are reversed. Cylinders (1A) and (3A) move forward; cylinder (2A) retracts and actuates the roller lever valve (2S1).

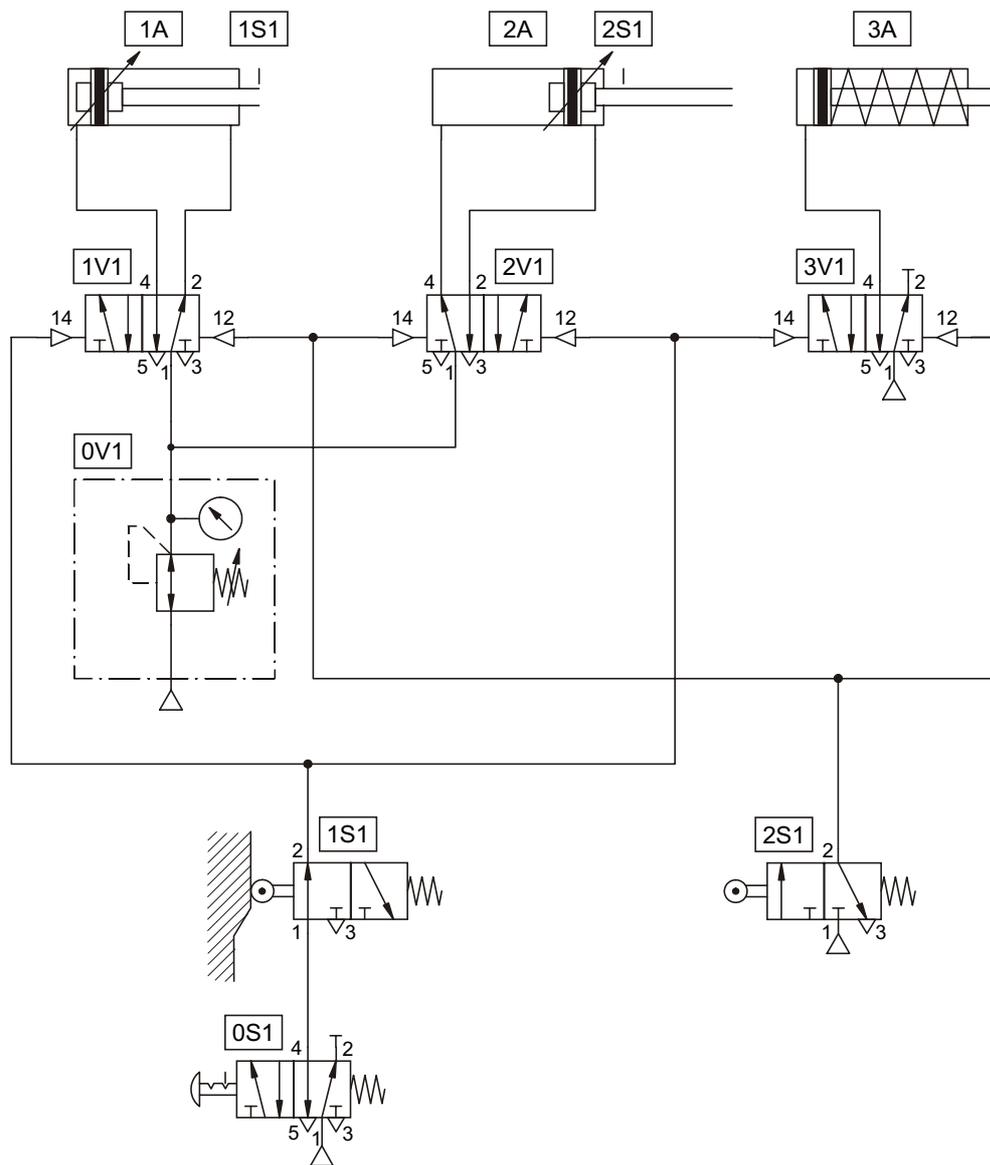
Step 2-3

Through the actuation of roller lever valve (2S1), all final control elements again reverse. Cylinder (2A) moves forward; cylinder (3A) retracts. Cylinder (1A) likewise retracts and again actuates the roller lever valve (1S1).

Continuous cycle

As long as valve (0S1) remains switched, the motion sequence will be repeated. If the valve (0S1) is brought to the initial start position, the system remains in its initial position at the end of a cycle.

Fig. 13/4: Circuit design



Components – service unit with on-off valve (0Z1) and manifold (0Z2), are no longer shown.



C-60

Solution 13

<i>Components list</i>	<i>Components</i>	<i>Description</i>
	0S1	5/2-way valve with selector switch
	0V1	Pressure regulator with pressure gauge
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Double-acting cylinder
	1S	3/2-way roller lever valve, normally closed
	1V	5/2-way double pilot valve
	2A	Double-acting cylinder
	2S1	3/2-way roller lever valve, normally closed
	2V1	5/2-way double pilot valve
	3A	Single-acting cylinder
	3V1	5/2-way double-pilot valve

Follow up The stroke time of cylinders is generally not the same. The time taken for one stroke is dependent on:

- cylinder dimensions
- power supplied (tubing size and pressure)
- external forces
- whether forward or return stroke etc.

Although all three cylinders are actuated from one signal generator, the three cylinders do not reach the end position at the same time. Observe these events in more detail.

- Draw up a modified displacement-step diagram.

On the assumption that the return strokes of cylinders (2A) and (1A) are the slowest, the following displacement-step diagram results.

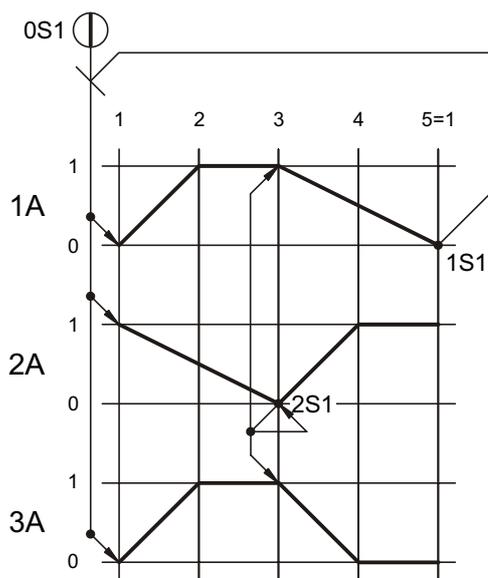


Fig. 13/5: Modified displacement-step diagram⁵

⁵ The modified displacement-step diagram with signal lines is not in accordance with VDI 3260.

C-62

Solution 13

Compactor for domestic rubbish

Fig. 14/3: Circuit diagram

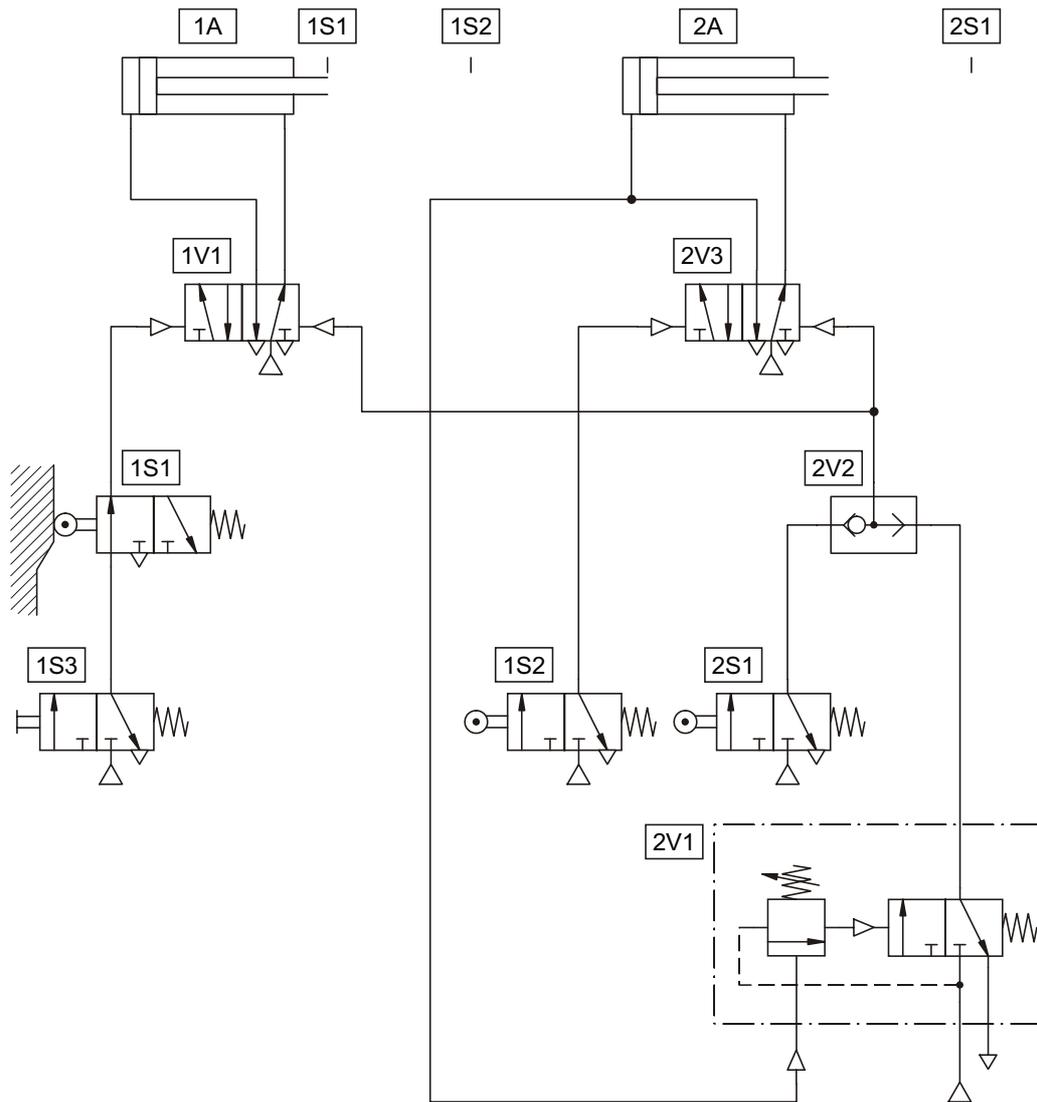
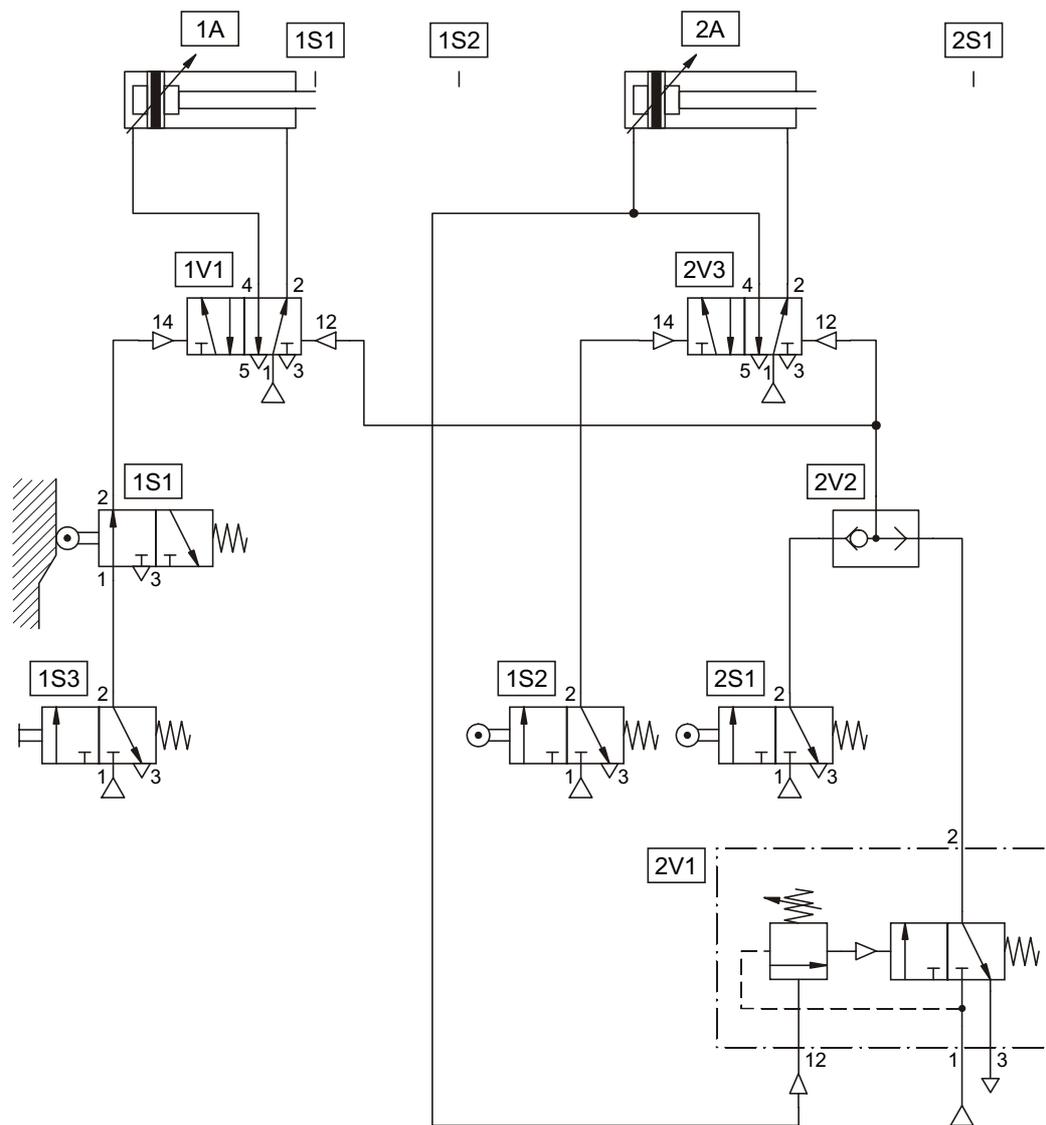


Fig. 14/4: Circuit design



If you fit one-way flow control valves between cylinders and power valves – also referred to as final control valve – (exhaust restriction during forward stroke), you are in a position to slow down the motion process considerably and thus improve control.



Components – service unit with on-off valve (0Z1) and manifold (0Z2) are no longer shown.

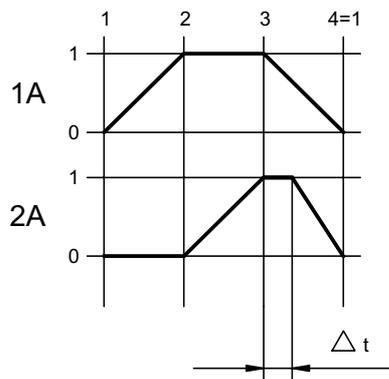
C-66

Solution 14

Components list	Components	Description
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Double-acting cylinder
	1S1	3/2-way valve with push button, normally closed
	1S2	3/2-way roller lever valve, normally closed
	1S3	3/2-way roller lever valve, normally closed
	1V1	5/2-way double pilot valve
	2A	Double-acting cylinder
	2S1	3/2-way roller lever valve, normally closed
	2V1	Pressure sequence valve
	2V2	Shuttle valve
	2V3	5/2-way double pilot valve

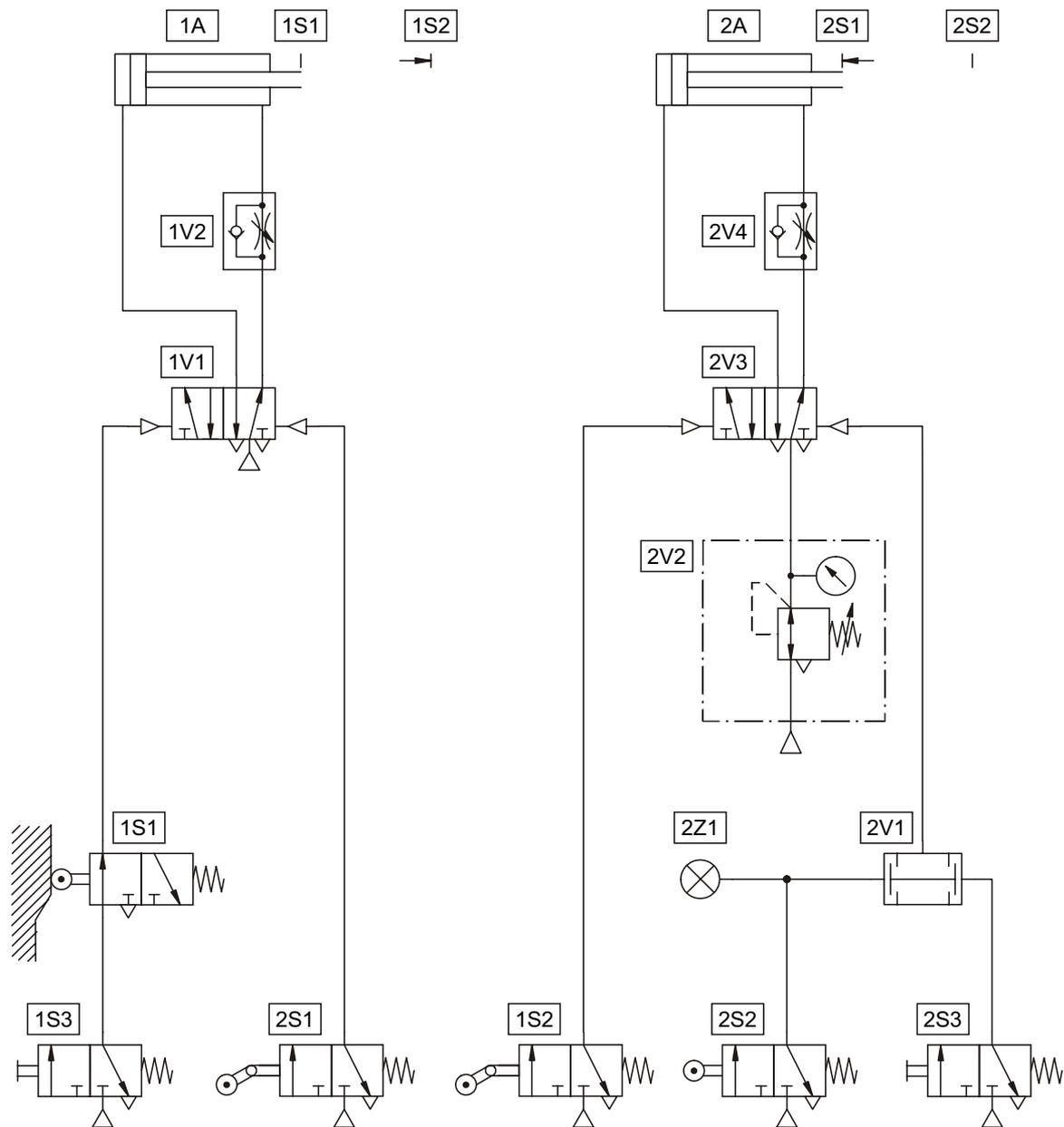
Time lag Δt is a delay during the return of the main compactor (2A) inherent in the system. Final control valve (2V) can reverse only when the trip cam of the pre-compactor (1A) no longer activates roller lever valve (1S3).

Fig. 14/5: Modified displacement-step diagram



Clamping camera housings

Fig. 15/2: Circuit diagram A

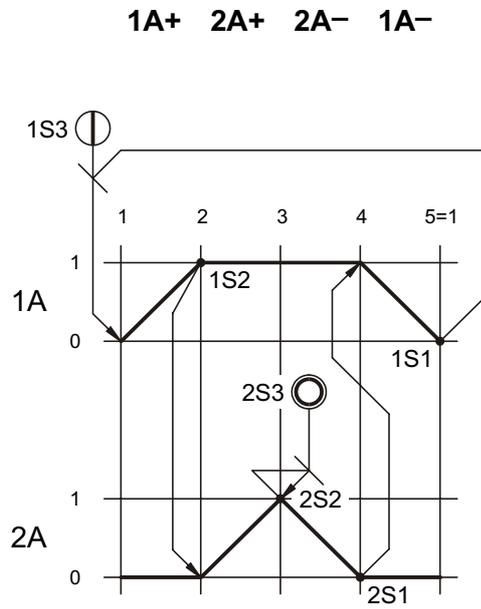


C-68

Solution 15

Abbreviated notation

Fig. 15/3: Displacement-step diagram



Initial position

In the initial position, the two cylinders (1A) and (2A) assume the retracted end position. The roller lever valve (1S1) is activated. The roller lever valve with idle return (2S1) is not activated.

Solution description

Step 1-2

When push button (1S3) is operated, a one-signal goes out to directional control valve (1V1) via the depressed roller lever valve (1S1). After the reversal of the 5/2-way double pilot valve (1V1), the cylinder (1A) advances with exhaust air restricted (1V2). Shortly before reaching the forward end position, the 3/2-way idle return roller lever valve (1S2) becomes actuated.

Step 2-3

The actuation of the idle return roller lever valve (1S2) reverses power valve (2V3); cylinder (2A) advances with its exhaust air restricted (2V4). With the actuation of roller lever valve (2S2) in the forward end position, the pneumatically activated optical indicator (2Z1) displays the one-signal. The control system remains in this position. The pressure regulator (2V2) limits the piston thrust (pressure limitation $p = 4 \text{ bar} = 400 \text{ kPa}$).

Step 3-4

With the operation of push button (2S3), power valve (2V3) is reversed through dual-pressure valve (2V1). The cylinder (2A) returns. Just before the retracted end position is reached, the trip cam triggers the roller lever (2S1).

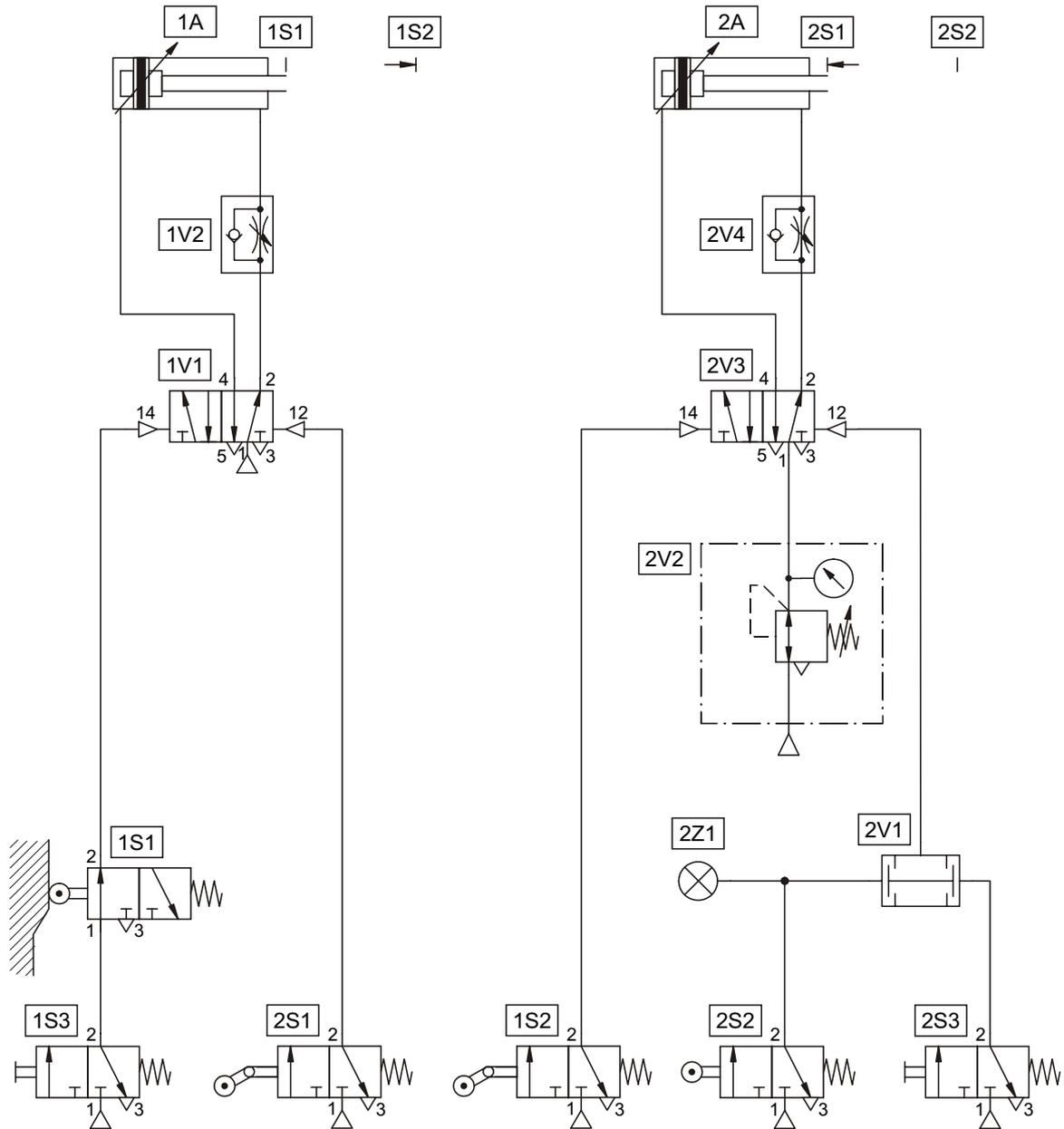
Step 4-5

Power valve (1V1) is reversed through the actuation of idle return roller lever valve (2S1). Cylinder (1A) returns. In the returned end position, the trip cam switches the start interlock (1S1).

C-70

Solution 15

Fig. 15/4: Circuit design



Components – service unit with on-off valve (0Z1) and manifold (0Z2) are no longer shown.

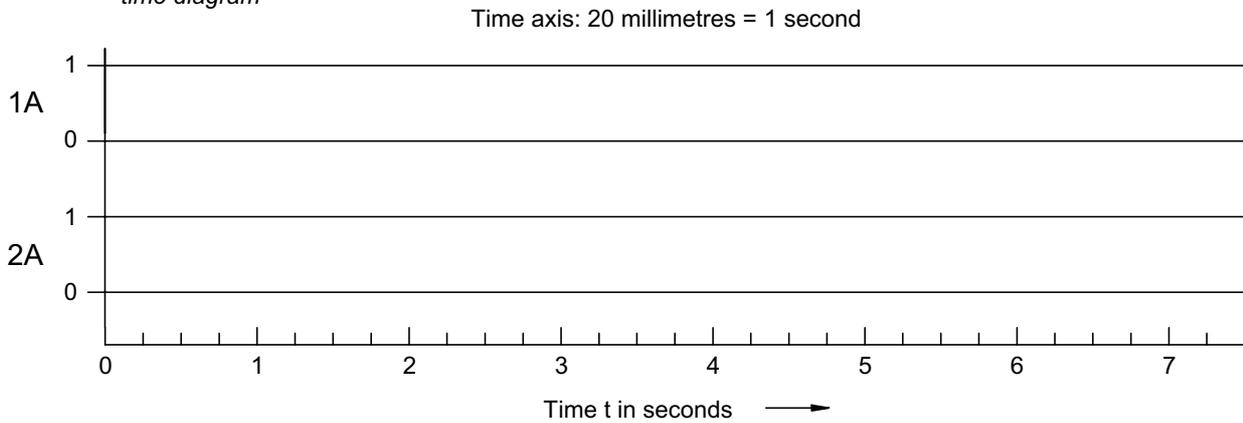
<i>Components</i>	<i>Description</i>	<i>Components list</i>
0Z1	Service unit with on-off valve	
0Z2	Manifold	
1A	Double-acting cylinder	
1S1	3/2-way valve with push button, normally closed	
1S2	3/2-way roller lever valve, normally closed	
1S3	3/2-way roller lever valve with idle return, normally closed	
1V1	5/2-way double pilot valve	
1V2	One-way flow control valve	
2A	Double-acting cylinder	
2S1	3/2-way roller lever valve with idle return, normally closed	
2S2	3/2-way roller lever valve, normally closed	
2S3	3/2-way valve with push button, normally closed	
2V1	Dual-pressure valve	
2V2	Pressure regulator with pressure gauge	
2V3	5/2-way double pilot valve	
2V4	One-way flow control valve	
2Z1	Optical display	

- Draw up the displacement-time diagram of the system you have built, using a stop watch. *Follow up*
- Replace the idle return roller lever valves (2S1) and (1S2) by ordinary roller lever valves. Why does the system no longer function?
- Write the abbreviated notation with division into groups (two groups).
- Build the alternative circuit B with a reversing valve.

C-72

Solution 15

Fig. 15/5: Displacement-time diagram



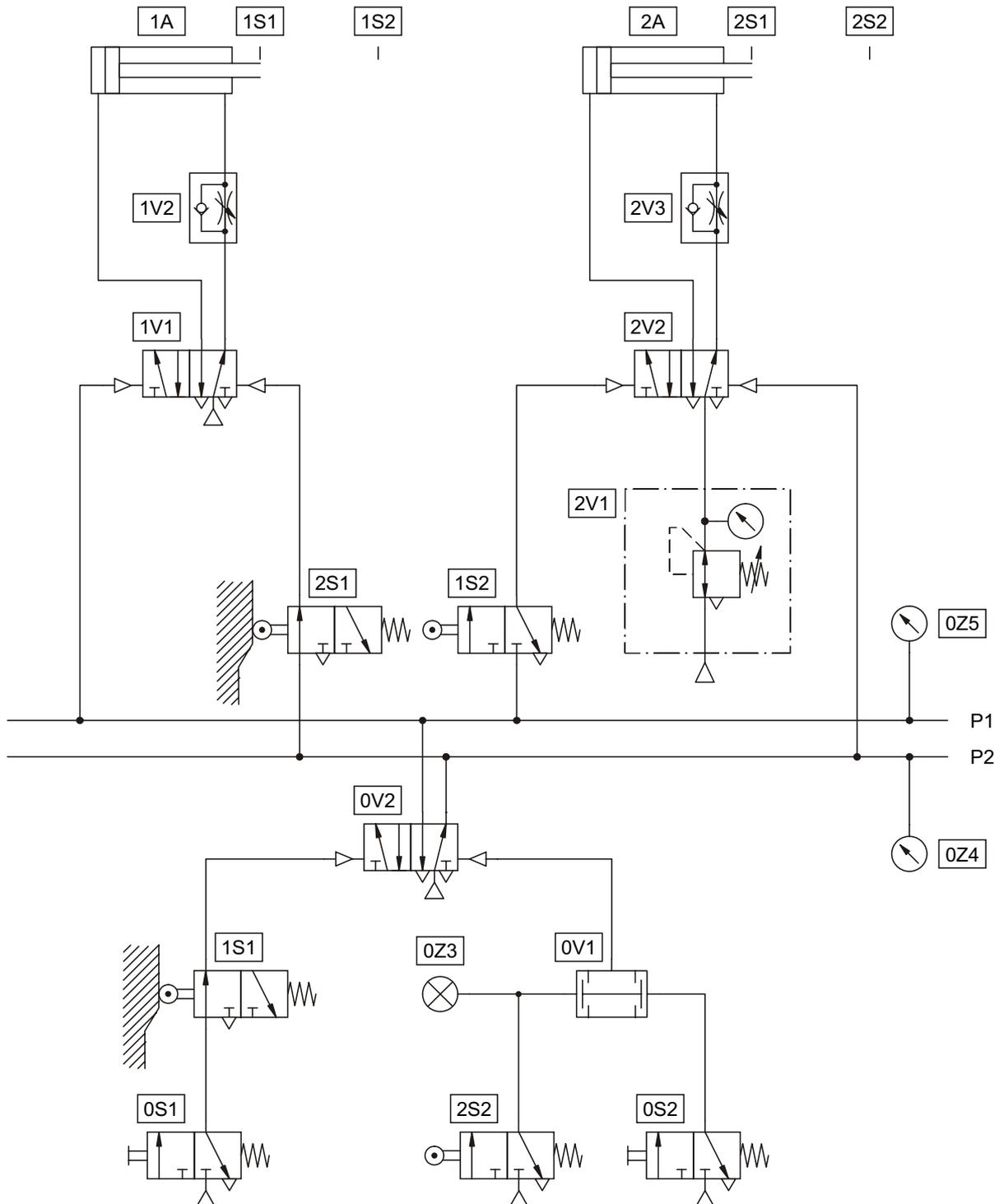
Abbreviated notation With division into groups for alternative circuit B

1A+	2A+	2A-	1A-
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One can see from the abbreviated notation that the motion sequence envisaged requires a division into at least two groups. A reversing valve is necessary in order to be able to form two separate circuits.

Note regarding solution The problem of switching off a counter signal still present at the power valves is solved here by using a reversing valve (0V2). In this way, one does not have to fit idle return roller lever valves. This increases operational reliability.

Fig. 15/6: Circuit diagram B

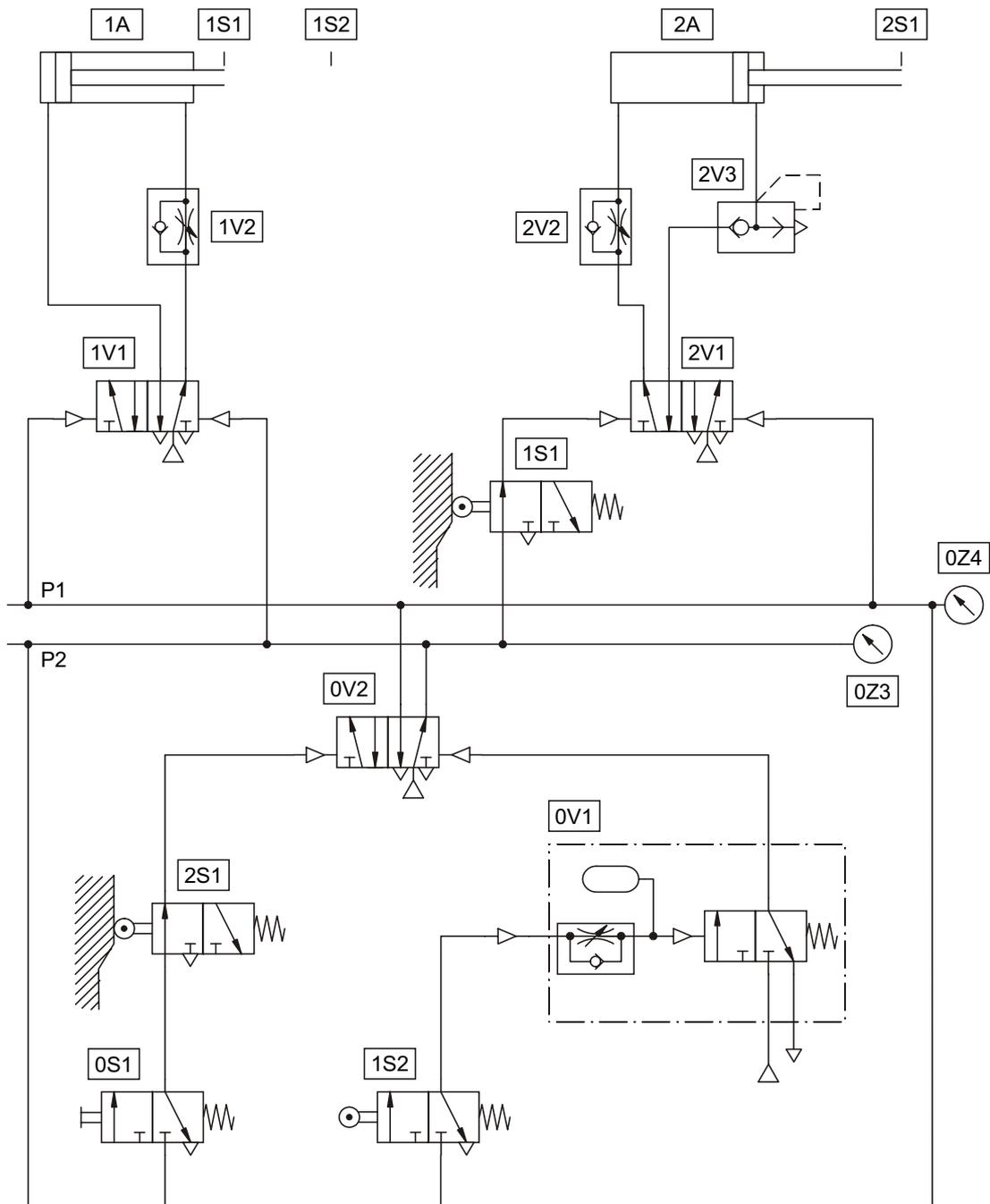


C-74

Solution 15

Input station for laser cutter

Fig. 16/2: Circuit diagram A

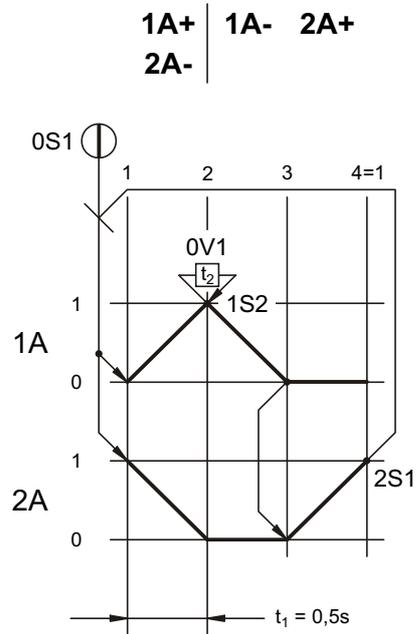


C-76

Solution 16

Abbreviated notation
with division into
groups

Fig. 16/3: Displacement-
step diagram



Initial position

In the initial position, the reversing valve (0V2) supplies air to line P2. The pressure gauge (0Z3) registers the signal. The clamping cylinder (1A) is retracted and actuates the roller lever valve (1S1). Ejector cylinder (2A) is advanced and actuates the roller lever valve (2S1).

Solution description

Step 1-2

If push button (0S1) is operated, reversing valve (0V2) switches and supplies air to line P1, line P2 is exhausted. Both power valves (1V1) and (2V1) are reversed. The ejector cylinder (2A) is retracted with its exhaust air restricted (2V2); at the same time clamping cylinder (1A) goes forward, likewise with exhaust air restricted (1V2) and actuates roller lever valve (1S2). Clamping time $t_1 = 0.5$ seconds is set by means of one-way flow control valves (1V2) and (2V2). Actuation of roller lever valve (1S2) supplies pressure to the pilot port of time delay valve (0V1). During the set clamping time of $t_2 = 5$ seconds, the air reservoir (pneumatic memory) of the time delay valve is filled.

Step 2-3

Switching through time delay valve (0V1) actuates reversing valve (0V2). Line P2 is pressurised (0Z3), line P1 exhausted (0Z4). After reversal of power valve, (1V1) clamping cylinder (1A) is retracted without restriction and, in its retracted end position, actuates roller lever valve (1S1).

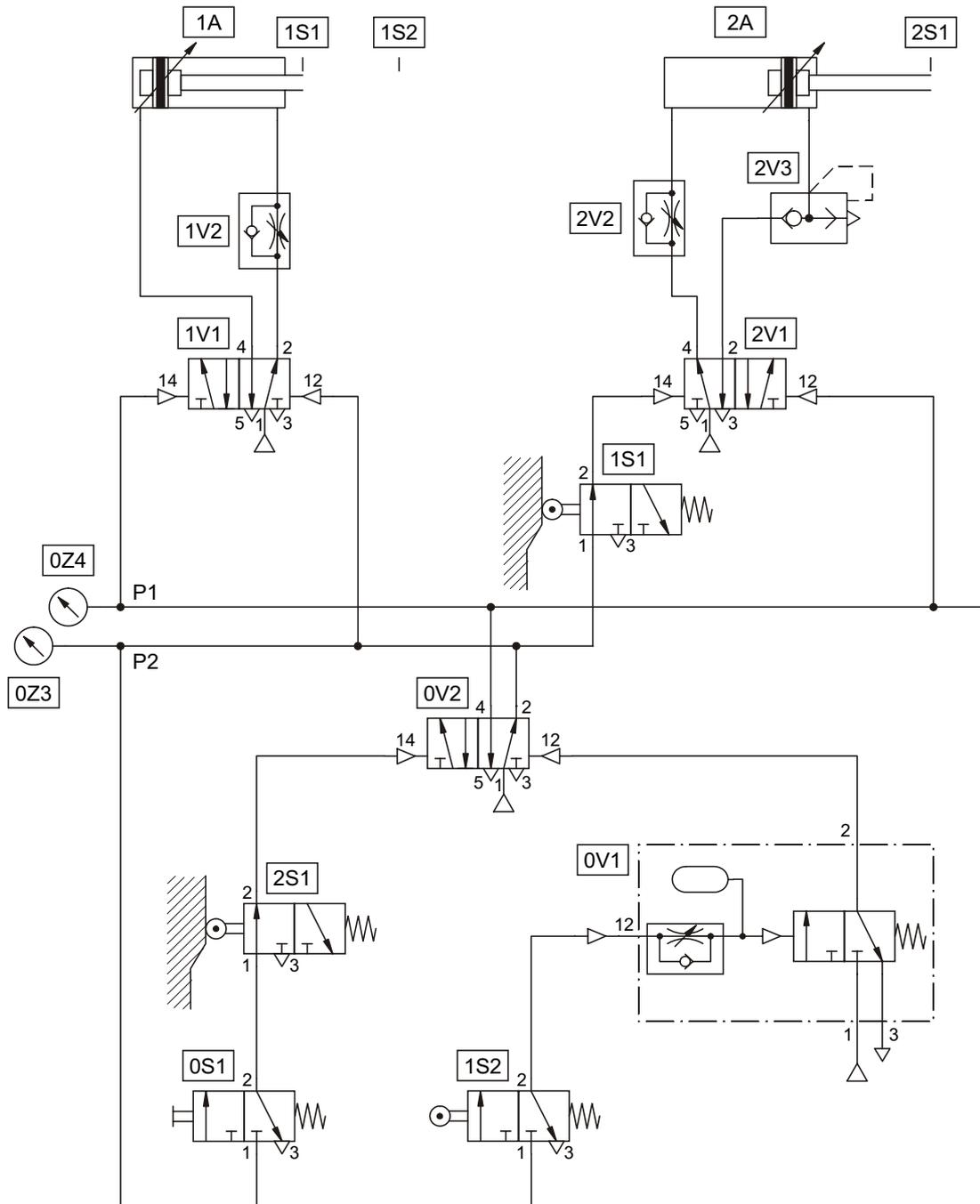
Step 3-4

After the actuation of roller lever valve (1S1), power valve (2V1) is reversed. Ejector cylinder (2A) advances rapidly. The fast forward motion is achieved through quick exhaust valve (2V3) and the shortest possible length of tubing between the cylinder and quick exhaust valve.

C-78

Solution 16

Fig. 16/4: Circuit design A



The components – service unit with on-off valve (0Z1) and manifold (0Z2) are no longer shown.

<i>Components</i>	<i>Description</i>	<i>Components list</i>
0S1	3/2-way valve with push button, normally closed	
0V1	Time delay valve, normally closed	
0V2	5/2-way double pilot valve	
0Z1	Service unit with on-off valve	
0Z2	Manifold	
0Z3	Pressure gauge	
0Z4	Pressure gauge	
1A	Double-acting cylinder	
1S1	3/2-way roller lever valve, normally closed	
1S2	3/2-way roller lever valve, normally closed	
1V1	5/2-way double pilot valve	
1V2	One-way flow control valve	
2A	Double-acting cylinder	
2S1	3/2-way roller lever valve, normally closed	
2V1	5/2-way double pilot valve	
2V2	One-way flow control valve	
2V3	Quick exhaust valve	

The following valve ports may also be connected directly to the air supply. *Follow up*

- Start push button 0S1 - 1
- Roller lever valve 1S2 - 1

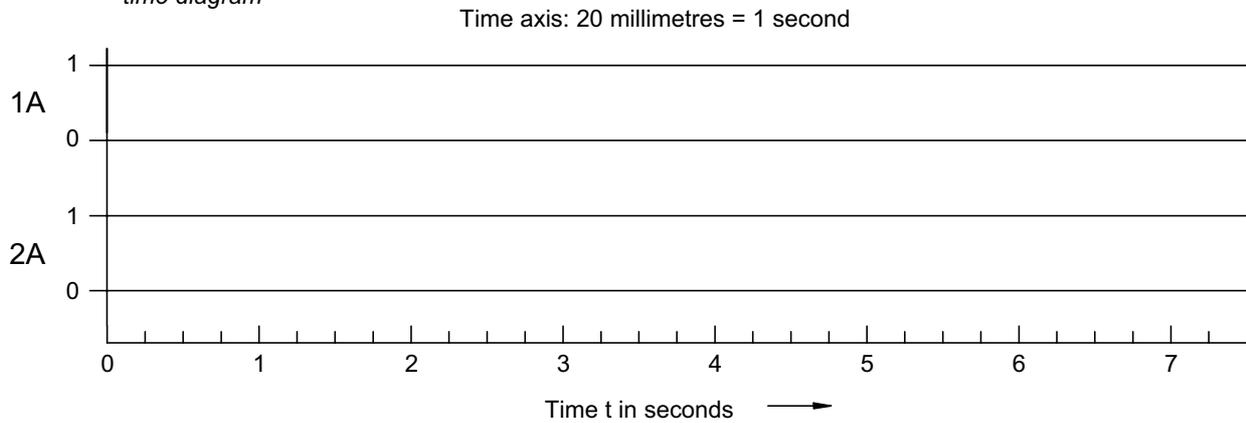
However, this reduces the reliability of operation.

- Draw up the displacement-time diagram of the assembled circuit by using a stop watch.

C-80

Solution 16

Fig. 16/5: Displacement-time diagram



Alternative circuits Assemble alternative circuits B, C and D. Investigate the advantages and disadvantages of the different alternatives.



Components – service unit with on-off valve (0Z1) and manifold (0Z2), are no longer shown.

C-82

Solution 16

Fig. 16/7:
Alternative circuit C
Circuit diagram

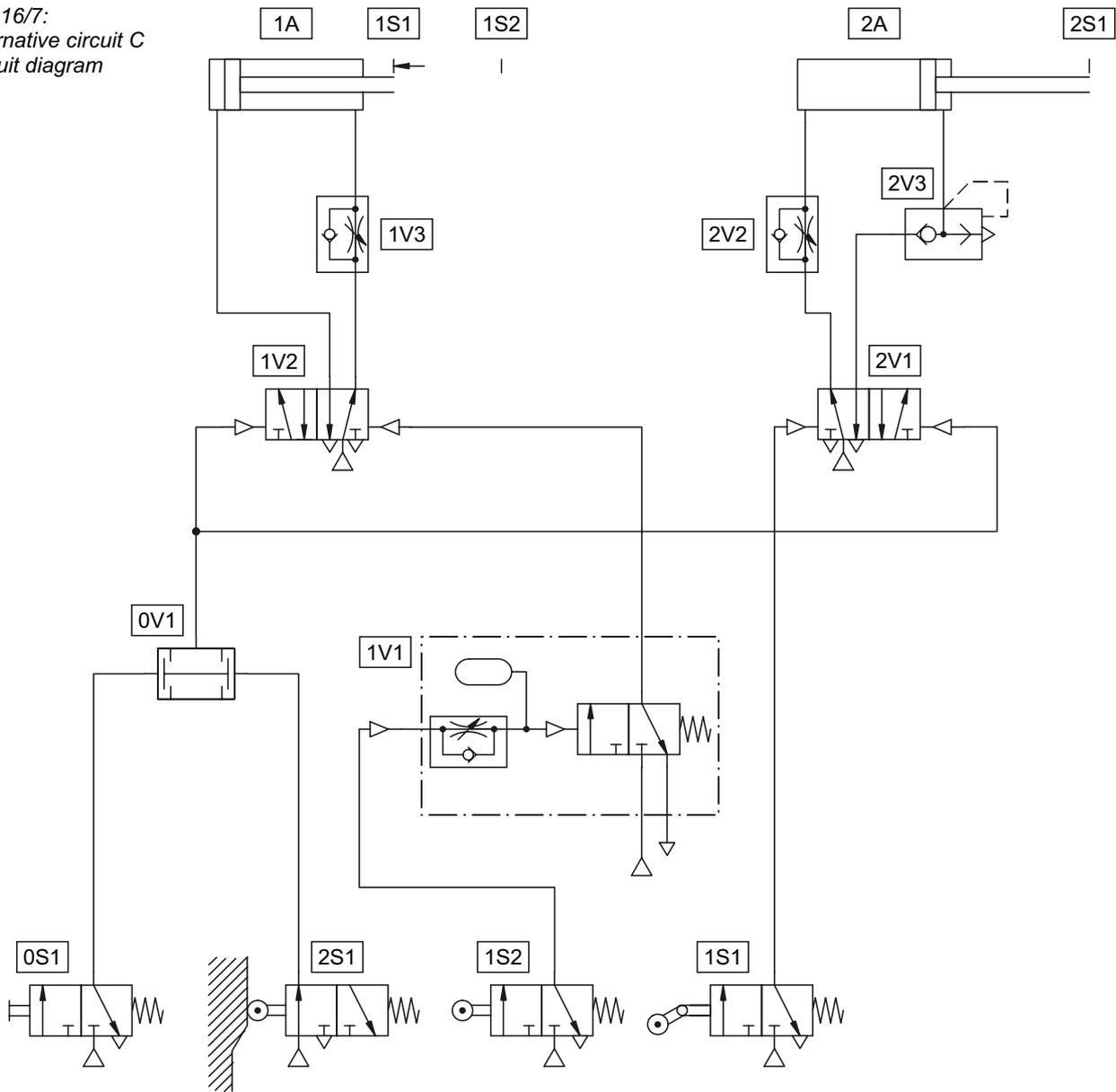
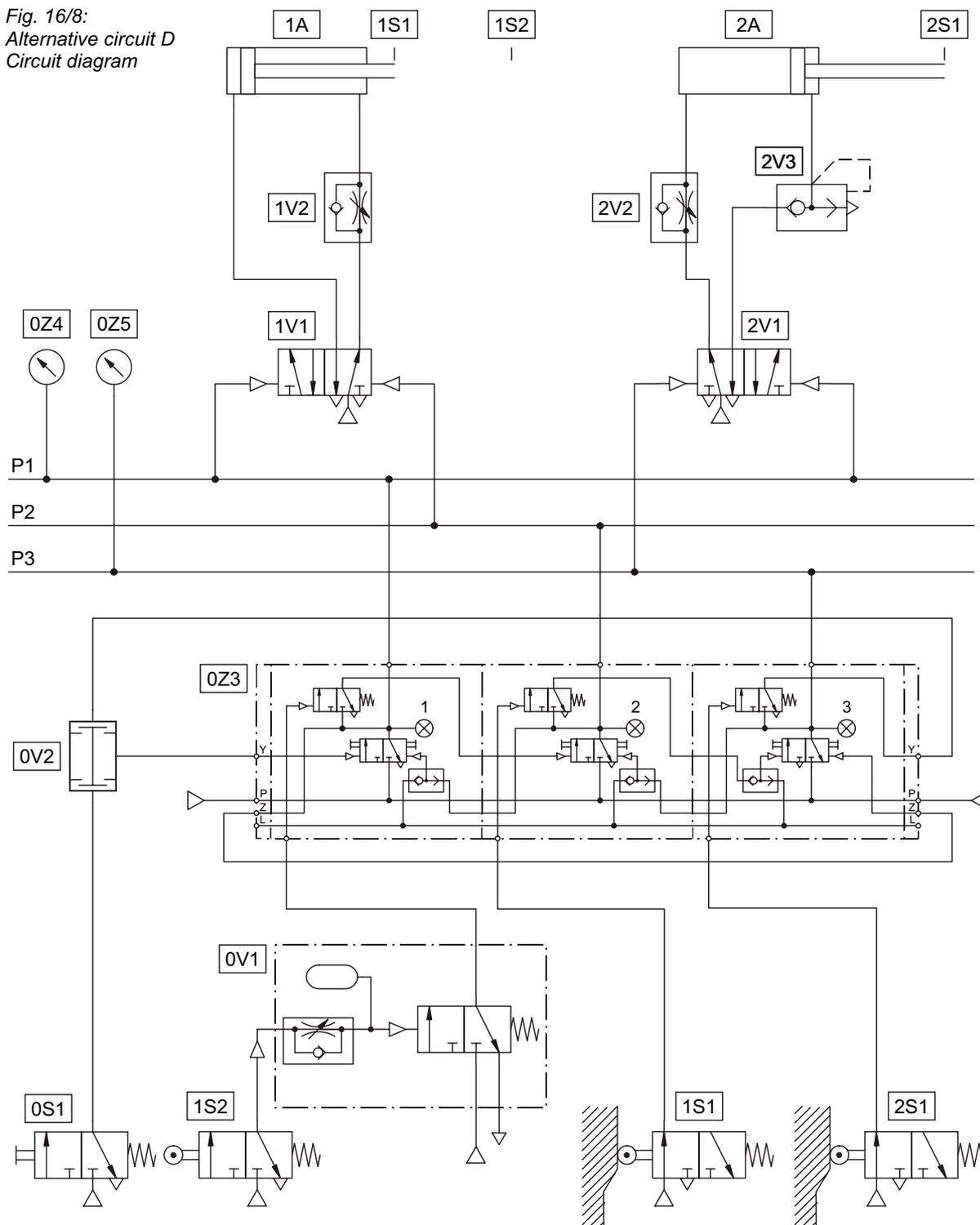


Fig. 16/8:
Alternative circuit D
Circuit diagram



C-84

Solution 16

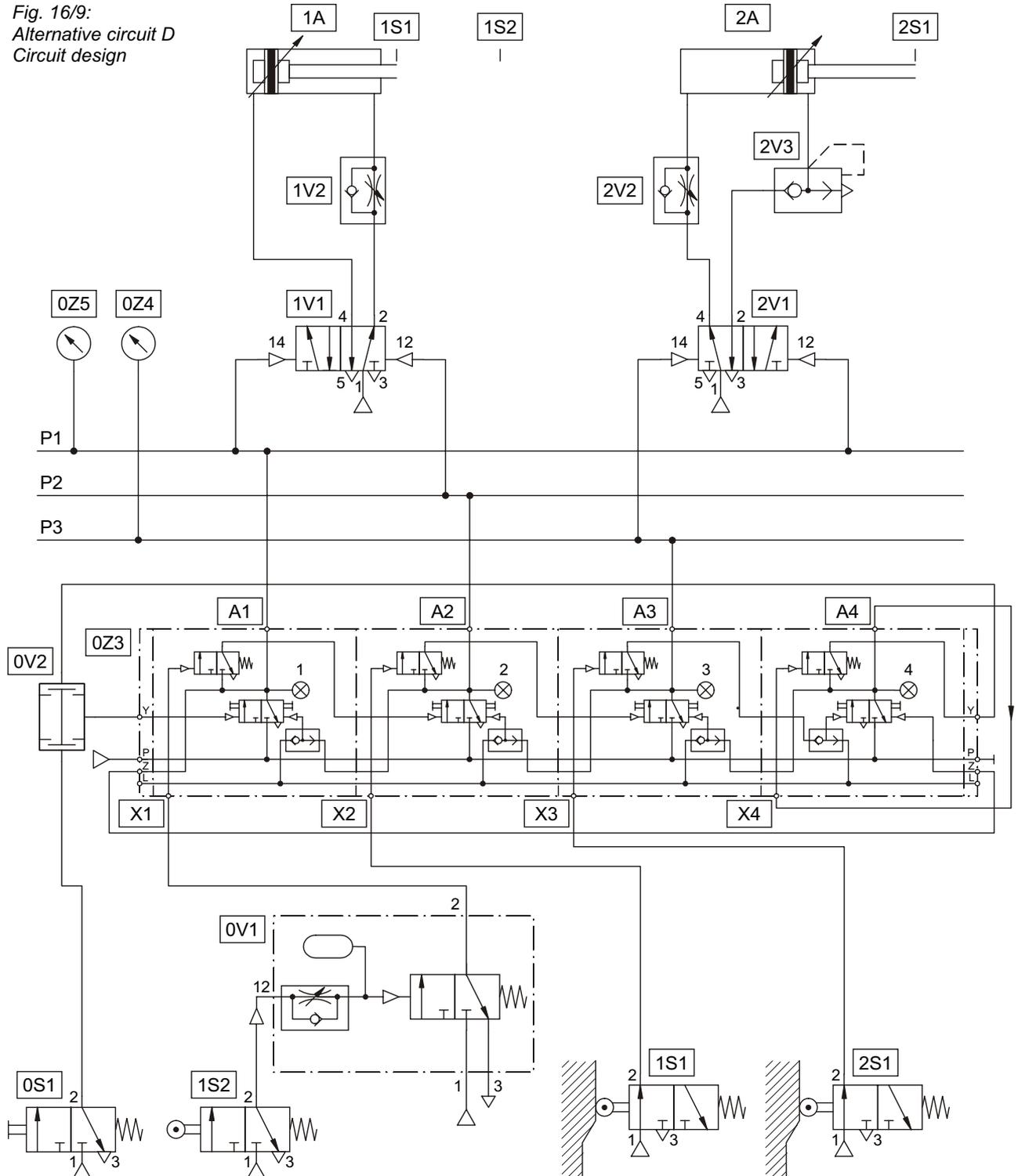
*Note regarding
this solution*

The Festo sequencer consists of at least three modules. It may be extended by any number of further modules. The Festo Didactic stepper modules of equipment set TP102 consist of four modules. Thus, when assembling the circuit, one step must be bridged (see also circuit design of this alternative circuit).



Fig. 16/9: Components – service unit with on-off valve (0Z1) and manifold (0Z2), are no longer shown.

Fig. 16/9:
Alternative circuit D
Circuit design



C-86

Solution 16

Partial automation of an internal grinder

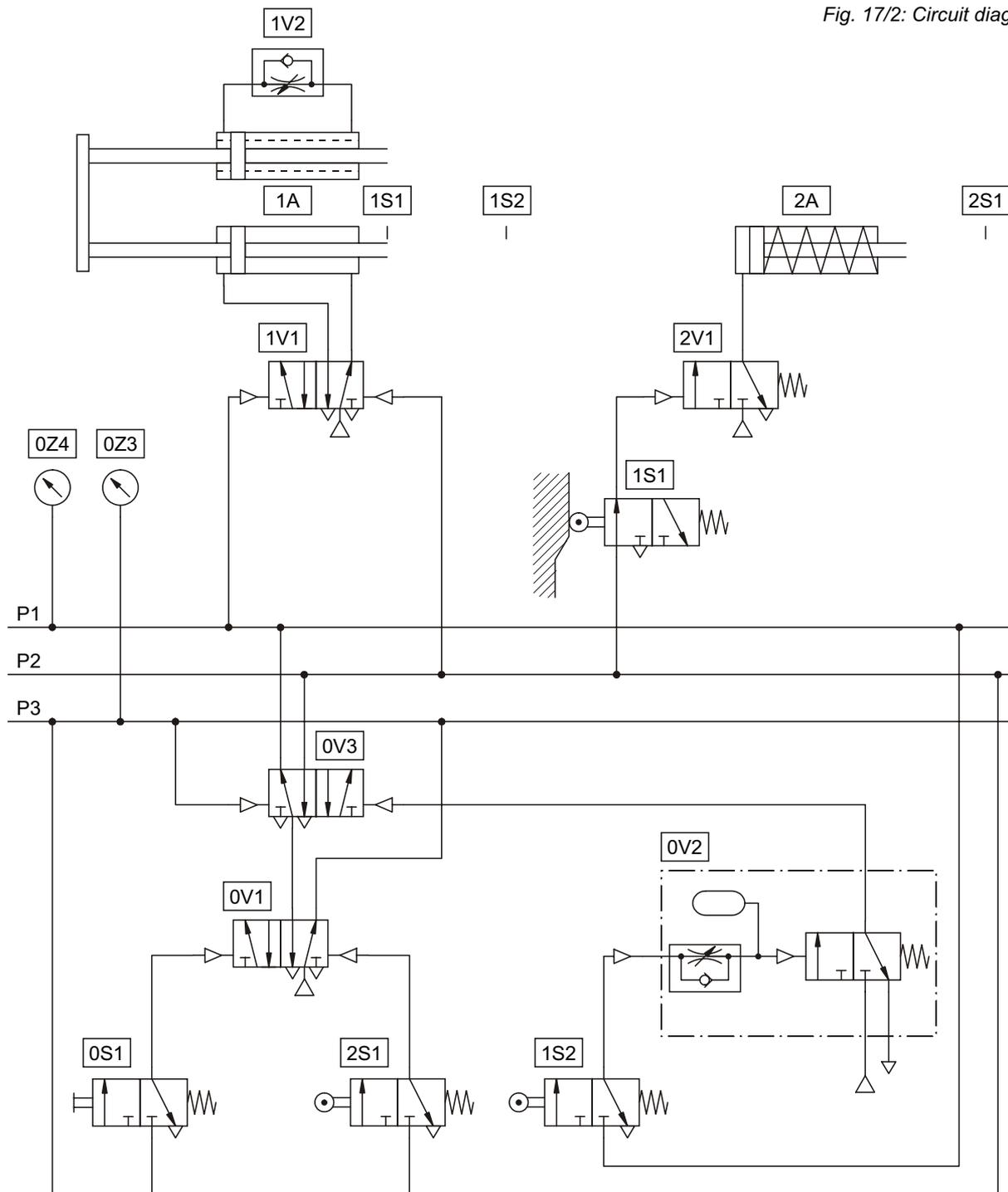


Fig. 17/2: Circuit diagram A

C-88

Solution 17



When this circuit is assembled, a double-acting cylinder takes the place of the pneumatic linear feed unit (1A).

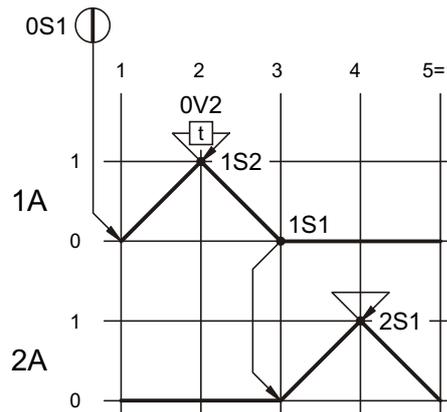
Abbreviated notation
with division into
groups

$1A+ \mid 1A- \quad 2A+ \mid 2A-$

It can be seen from the abbreviated notation, that the preset sequence of movements requires a division into at least two groups. For setting up two lines, one reversing valve is needed.

If a separation into groups is undertaken at the beginning of the cycle, three groups result. For three lines, it is necessary to connect up two reversing valves in series.

Fig. 17/3: Displacement-step diagram



Initial position

In the initial position, both cylinders assume the retracted end position. Roller lever valve (1S1) is actuated. The upper reversing valve (0V3) is in the right-hand switching position. Line P3 is pressurised through the left hand switching position assumed by reversing valve (0V1).

Solution description

Step 1-2

Operation of start push button (0S1) actuates the lower reversing valve (0V1) and provides pressure to line P1 while exhausting line P3. Power valve (1V1) reverses and pneumatic linear feed (1A) advances. In the forward end position, the actuator triggers roller lever valve (1S2). This supplies pressure at the pilot port of time delay valve (0V2). The actuator (1A) remains in the forward end position during $t = 2$ seconds.

Step 2-3

Switching through of the time delay valve (0V2) causes the upper reversing valve (0V3) to switch and line P2 to be pressurised. Power valve (1V1) is reset. Feed cylinder (1A) goes to its initial position and again actuates roller lever valve (1S1).

Step 3-4

As line P2 is pressurised, actuation of roller lever valve (1S1) causes power valve (2V1) to be switched against spring force. Ejector cylinder (2A) goes forward unthrottled and actuates roller lever valve (2S1).

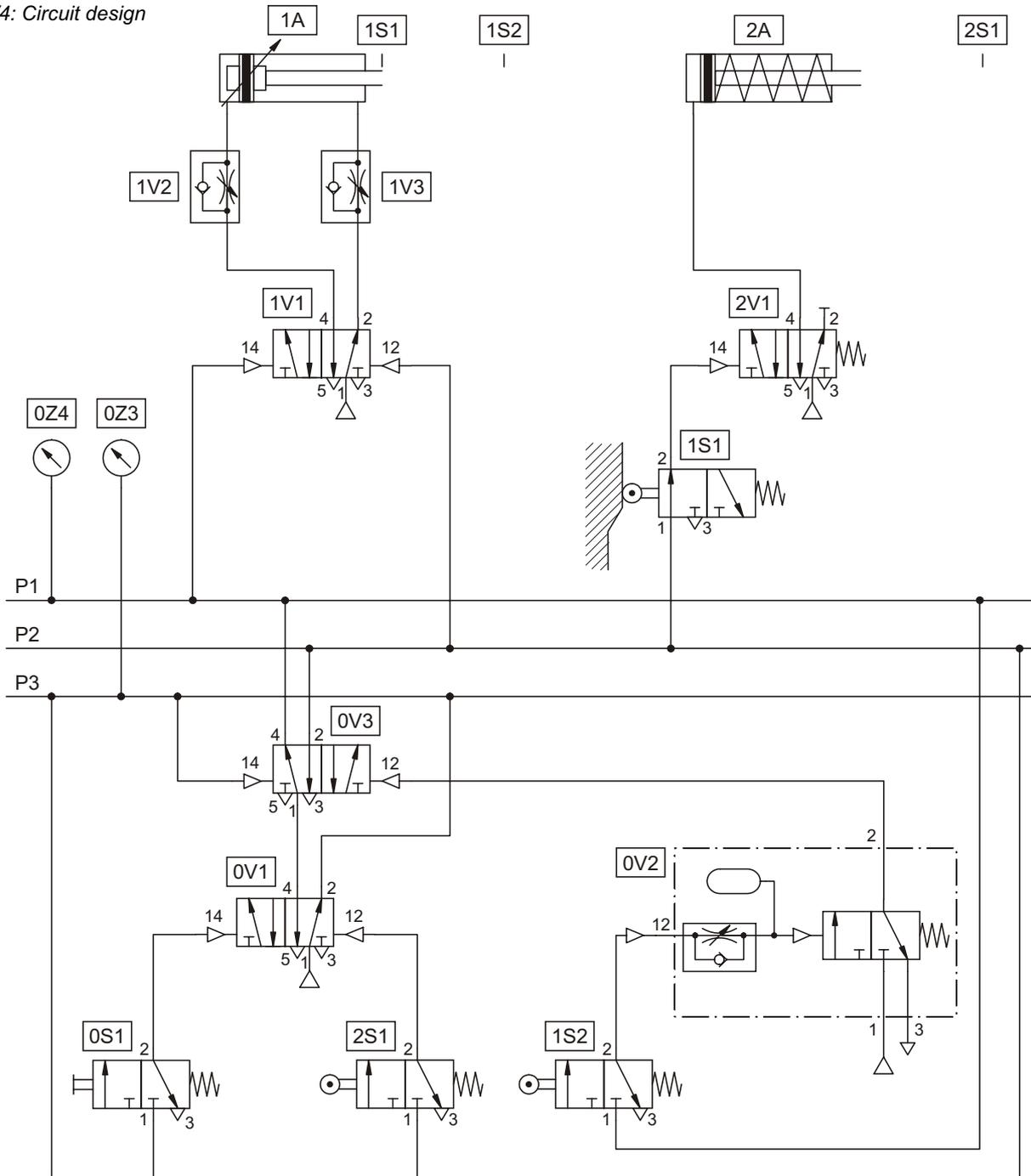
Step 4-5

Actuation of limit switch (2S1) causes lower reversing valve (0V1) to be switched. This change of status has two effects. Firstly, line P3 is pressurised and the upper reversing valve put into the right-hand switching position, so that both reversing valves (0V1) and (0V3) are back in the initial position. Secondly, line P2 is exhausted. This leads to the resetting of power valve (2V1) and thus, to the retraction of the ejector cylinder (2A).

C-90

Solution 17

Fig.17/4: Circuit design



In the set of equipment for the basic level, there are three 5/2-way double pilot valves, (0V1), (0V3) and (1V1). In place of power valve (2V1) with spring return, a fourth 5/2-way double piloted valve may be used. The right-hand pilot port 2V1-12 is then connected to line P3.



Components – service unit with on-off valve (0Z1) and manifold (0Z2), are no longer shown.

Components	Description
0S1	3/2-way valve with push-button, normally closed
0V1	5/2-way double pilot valve
0V2	Time delay valve, normally closed
0V3	5/2-way double pilot valve
0Z1	Service unit with on-off valve
0Z2	Manifold
0Z3	Pressure gauge
0Z4	Pressure gauge
1A	Double-acting cylinder
1S1	3/2-way roller lever valve, normally closed
1S2	3/2-way roller lever valve, normally closed
1V1	5/2-way double pilot valve
1V2	One-way flow control valve
1V3	One-way flow control valve
2A	Single-acting cylinder
2S1	3/2-way roller lever valve, normally closed
2V1	5/2-way single pilot valve

Components list

- Construct alternative circuits B and C. Find out the advantages and disadvantages of the various alternatives.

Follow up

C-92

Solution 17

Fig. 17/5:
Alternative circuit B
Circuit diagram

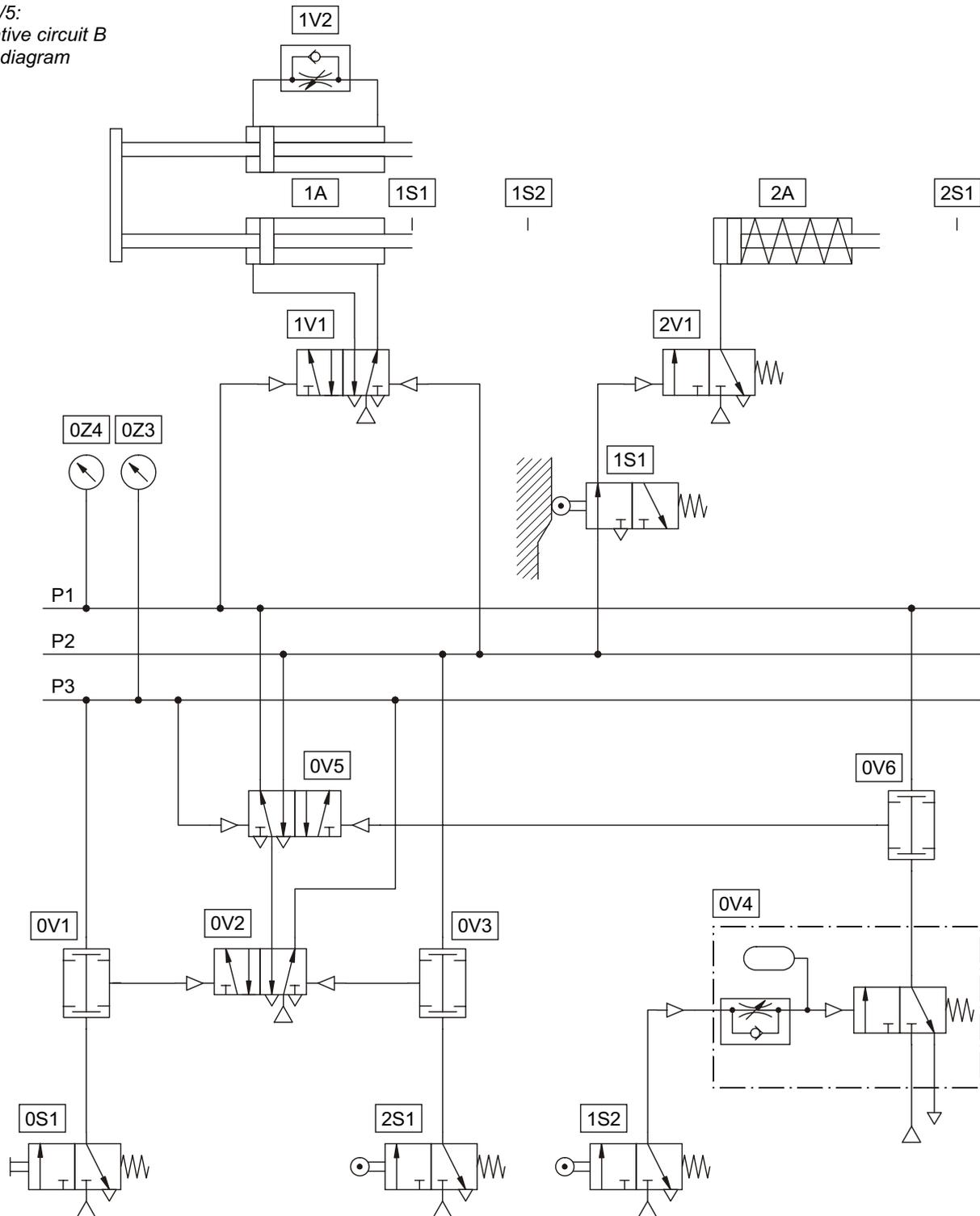
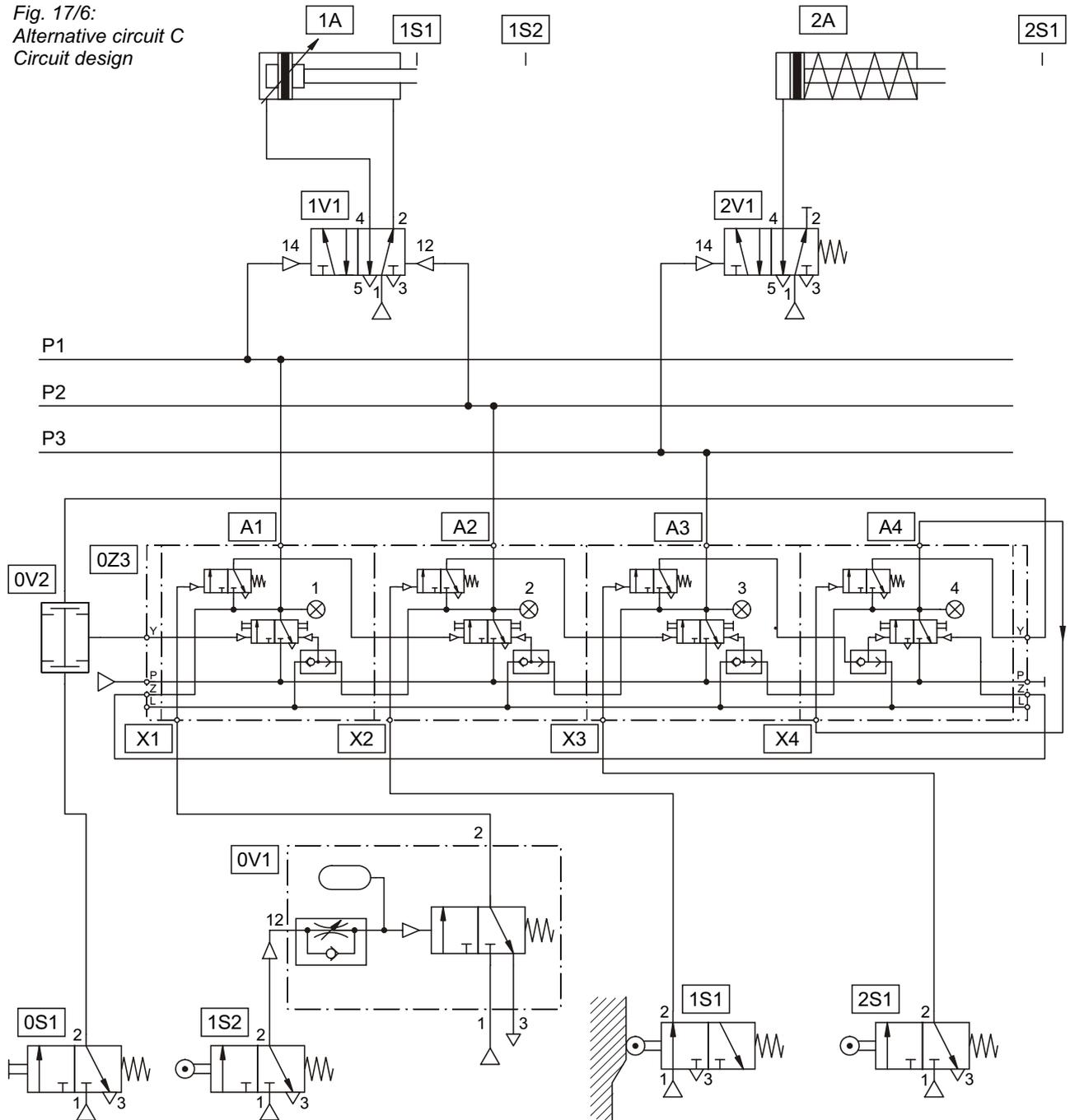


Fig. 17/6:
Alternative circuit C
Circuit design



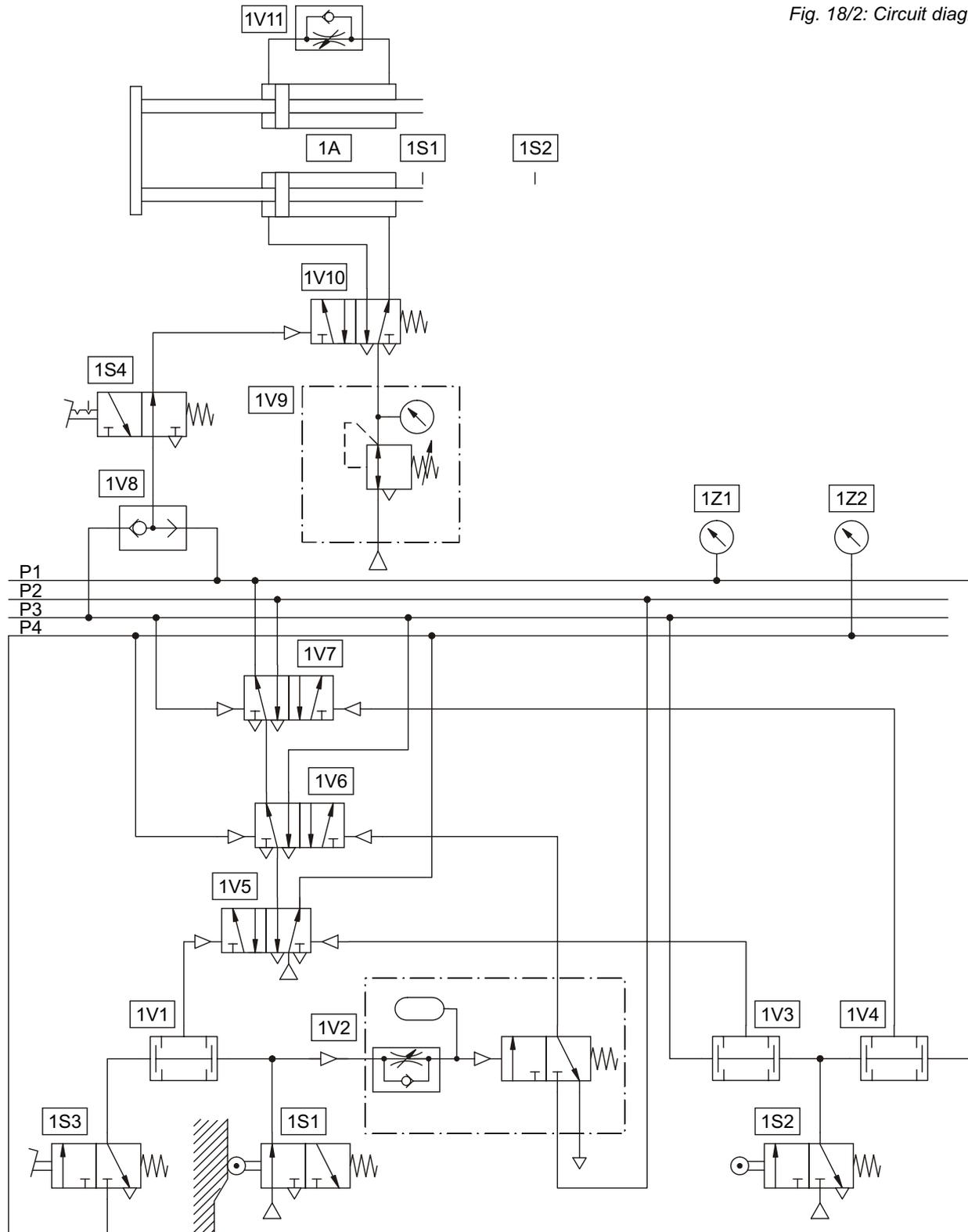
Components – service unit with on-off valve (0Z1) and manifold (0Z2), are no longer shown..

C-94

Solution 17

Drilling machine with four spindles

Fig. 18/2: Circuit diagram A





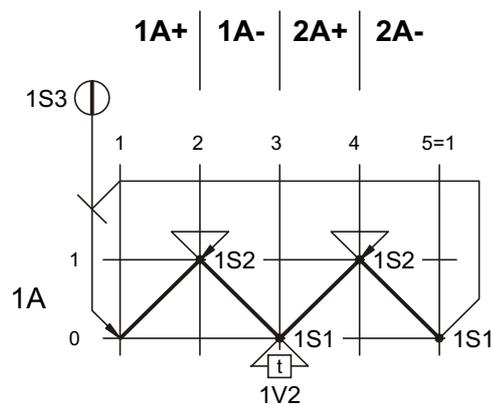
When this circuit is assembled, the “foot-actuated” 3/2-way valves (1S1) and (1S4) are replaced by valves with push button or selector switch

- (1S1) 3/2-way valve, by push button
- (1S4) 5/2-way valve, by selector switch

The feed unit (1A) is replaced by a double-acting cylinder.

Abbreviated notation
with division into
groups

Fig. 18/3: Displacement-
step diagram



Solution description Initial position

In the initial position, the cylinder (1A) assumes the retracted end position. The final control valve (1V10) is located in the left switching position and supplies air to the piston rod chamber. Line P4 is pressurised; the other three lines are exhausted. The upper reversing valve (1V7) and the central reversing valve (1V6) are located in the right-hand switching position. The lower reversing valve (1V5) assumes the left-hand switching position. The roller lever valve (1S1) is actuated.

Step 1-2

The lower reversing valve (1V5) is actuated by depressing the start valve by pedal (1S3). Line P4 exhausts and line P1 is supplied with air. The final control valve (1V10) is reversed via the shuttle valve (1V8) and the 3/2-way valve (1S4). The cylinder extends with flow control. The trip cam actuates the roller lever valve (1S2) in the forward end position.

Step 2-3

The upper reversing valve (1V7) is actuated via the dual-pressure valve (1V4) and by actuating the roller lever valve (1S2). Line P1 is exhausted. Line P2 is supplied with air and the time delay valve (1V2) is pressurised at the supply port with a one-signal. Exhausting line P1 reverses the final control valve (1V10); the cylinder retracts. In the retracted end position, the trip cam re-actuates the roller lever valve (1S1). The control port of the time delay valve (1V2) is now supplied with air by renewed actuation of the roller lever valve. The pneumatic reservoir is filled via the restrictor. The cylinder is held in the retracted end position for $t = 1.5$ seconds.

Step 3-4

Time delay valve (1V2) switches through at a reservoir pressure $p = 3$ bar ($= 300$ kPa), and the central reversing valve (1V6) is thus transferred into the left switching position. Line P2 is exhausted, and line P3 is supplied with air. This leads initially to the upper reversing valve (1V7) being reset to the initial start position. Secondly, the dual-pressure valve (1V3) is supplied with pressure on one side. Thirdly, the final control valve (1V10) is reversed once again and the cylinder extends a second time. The trip cam re-actuates the roller lever valve (1S2) in the forward end position.

Step 4-5

The re-actuation of the roller lever valve (1S2) switches through the dual-pressure valve (1V3) and actuates the lower reversing valve (1V5). The central reversing valve (1V6) is also reset and, by exhausting line P3, the final control valve (1V10) is exhausted on the control side causing the drilling spindles to retract a second time. The roller lever valve (1S1) is actuated a final time in the retracted end position. The three reversing valves are once again in the initial position, i. e. the final line is supplied with air. The other lines are exhausted.

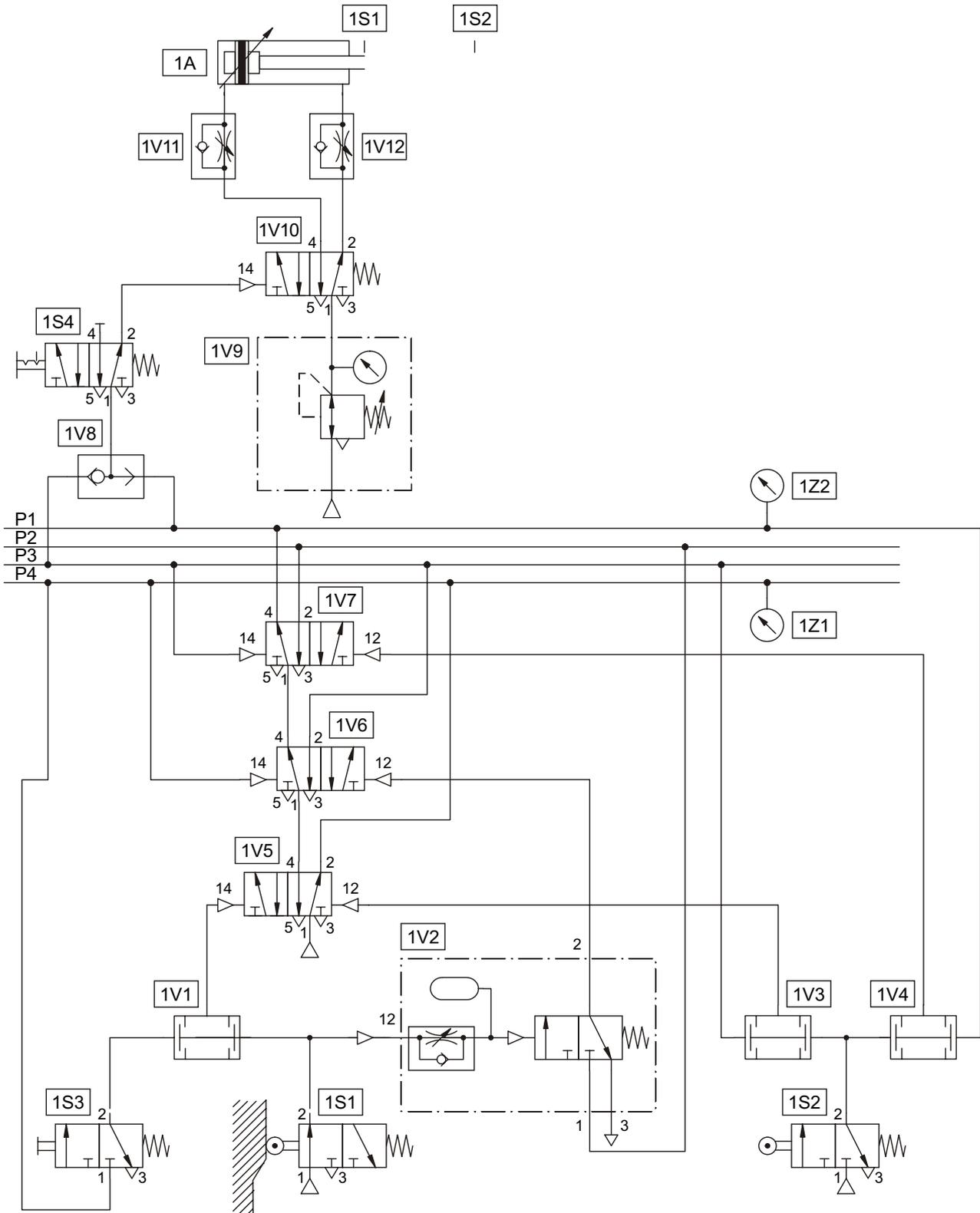
3/2-way valve (1S4) with flow in the normal position

If more time is required to move the spacer than was foreseen, the advance of the cylinder can be prevented through actuation of valve (1S4). Any movement which has been initiated is interrupted and the cylinder travels to the retracted end position. If the detent of the 3/2-way normally open valve (1S4) is unlatched, the motion sequence proceeds as normal.

C-98

Solution 18

Fig. 18/4: Circuit design



The components – service unit with on-off valve (0Z1), and manifold (0Z2), are no longer shown.



Components	Description
0Z1	Service unit with on-off valve
0Z2	Manifold
1A	Double-acting cylinder
1S1	3/2-way roller lever valve, normally closed
1S2	3/2-way roller lever valve, normally closed
1S3	3/2-way valve with push button, normally closed
1S4	5/2-way valve with selector switch
1V1	Dual-pressure valve
1V2	Time delay valve, normally closed
1V3	Dual-pressure valve
1V4	Dual-pressure valve
1V5	5/2-way double pilot valve
1V6	5/2-way double pilot valve
1V7	5/2-way double pilot valve
1V8	Shuttle valve
1V9	Pressure regulator with pressure gauge
1V10	5/2-way single pilot valve
1V11	One-way flow control valve
1V12	One-way flow control valve
1Z1	Pressure gauge
1Z2	Pressure gauge

Components list

- Construct alternative circuit B. What advantages are afforded by circuit B?

Follow up

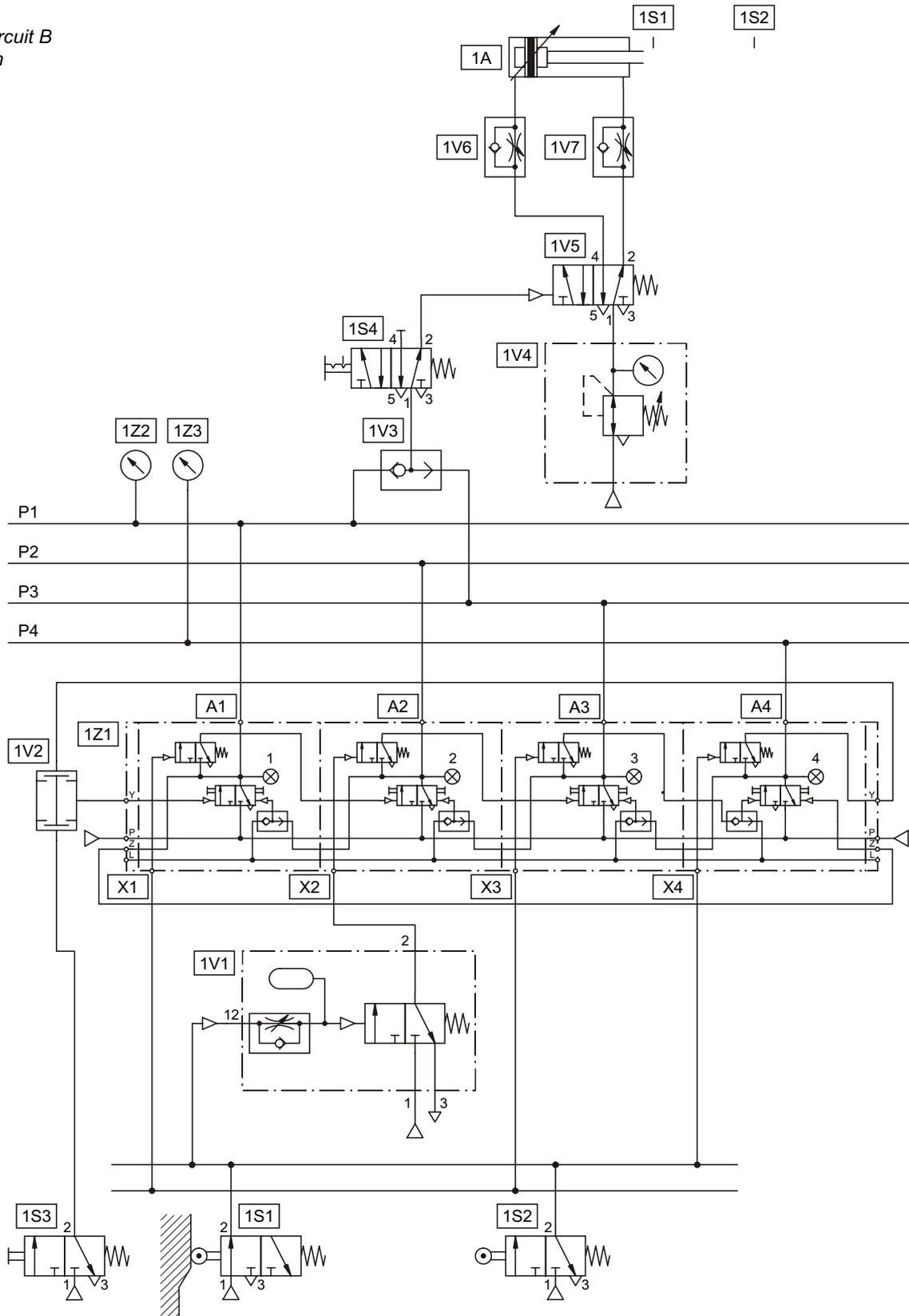
Fig. 18/5: The components – service unit with on-off valve (0Z1), and manifold (0Z2), are no longer shown.



C-100

Solution 18

Fig. 18/5:
Alternative circuit B
Circuit design



C-102

Solution 19

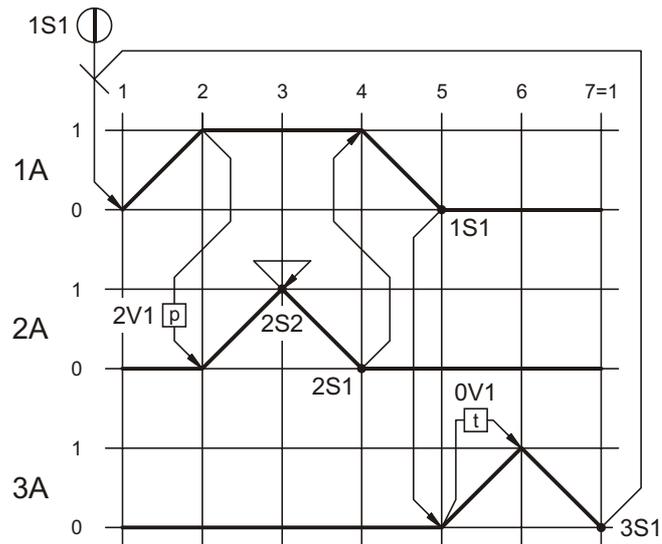
Abbreviated notation
with division into
groups

$$1A+ \quad 2A+ \quad | \quad 2A- \quad 1A- \quad 3A+ \quad | \quad 3A-$$

From the abbreviated notation, it can be seen that the preset motion sequence needs to be divided into a least two groups (minimum division). A reversing valve is necessary for the formation of two lines.

However, this circuit is not very reliable. To achieve a greater degree of reliability, it is necessary either to bring into use components from a second basic level equipment set (TP101) or else to use components from the advanced level (TP102). Please also note alternative solution B.

Fig. 19/4: Displacement-step diagram



Initial position

In the initial position, all three cylinders assume the retracted end position. The clamping cylinder (1A) actuates roller lever valve 1S1). Roller lever valve (2S1) is depressed by feed cylinder (2A). Line P1 is exhausted. Line P2 is supplied with air as reversing valve (0V2) assumes the left-hand switching position.

Solution description

Step 1-2

Actuation of the start button (1S2) causes the final control element (1V3) to reverse. Clamping cylinder (1A) with exhaust air throttled (1V4), pushes the end piece out of the magazine and under the drilling spindle and holds it in a clamped position against the fixed stop. The pressure continues to rise in the clamping cylinder (1A). When a pressure of $p = 4$ bar (= 400 kPa) has been reached in the cylinder, the pressure sequence valve (2V1) switches.

Step 2-3

With the switching through of pressure sequence valve (2V1), also supplied with air from line P2, final control valve (2V3) is reversed against the spring. Feed cylinder (2A) extends with flow control (2V4). Roller lever valve (2S2) is actuated in the forward end position.

Step 3-4

Once the forward end position has been reached, the workpiece cylinder (2A) returns to its initial start position. The return stroke is initiated by the actuation of the roller lever valve (2S2), which causes the reversing valve (0V2) to be reversed. Line P1 is supplied with air. Line P2 is exhausted and the final control component (2V3) returns independently. Feed cylinder (2A) actuates roller lever valve (2S1) in the retracted end position.

Step 4-5

When the roller lever valve (2S1) switches through, the final control valve (1V3) reverses, as line P1 is now exhausted. The clamping cylinder (1A) returns without flow control. In the retracted end position, the cylinder trip cam depresses the lever of the roller lever valve (1S1).

Step 5-6

Final control element (3V1) is reversed by actuating roller lever valve (1S1). Ejecting cylinder (3A) pushes the finished end piece out of the machine. At the same time, the pneumatic reservoir of the time delay valve (0V1) is filled via the restrictor. The time delay valve (0V1) is actuated at a control pressure of $p = 3 \text{ bar} (= 300 \text{ kPa})$.

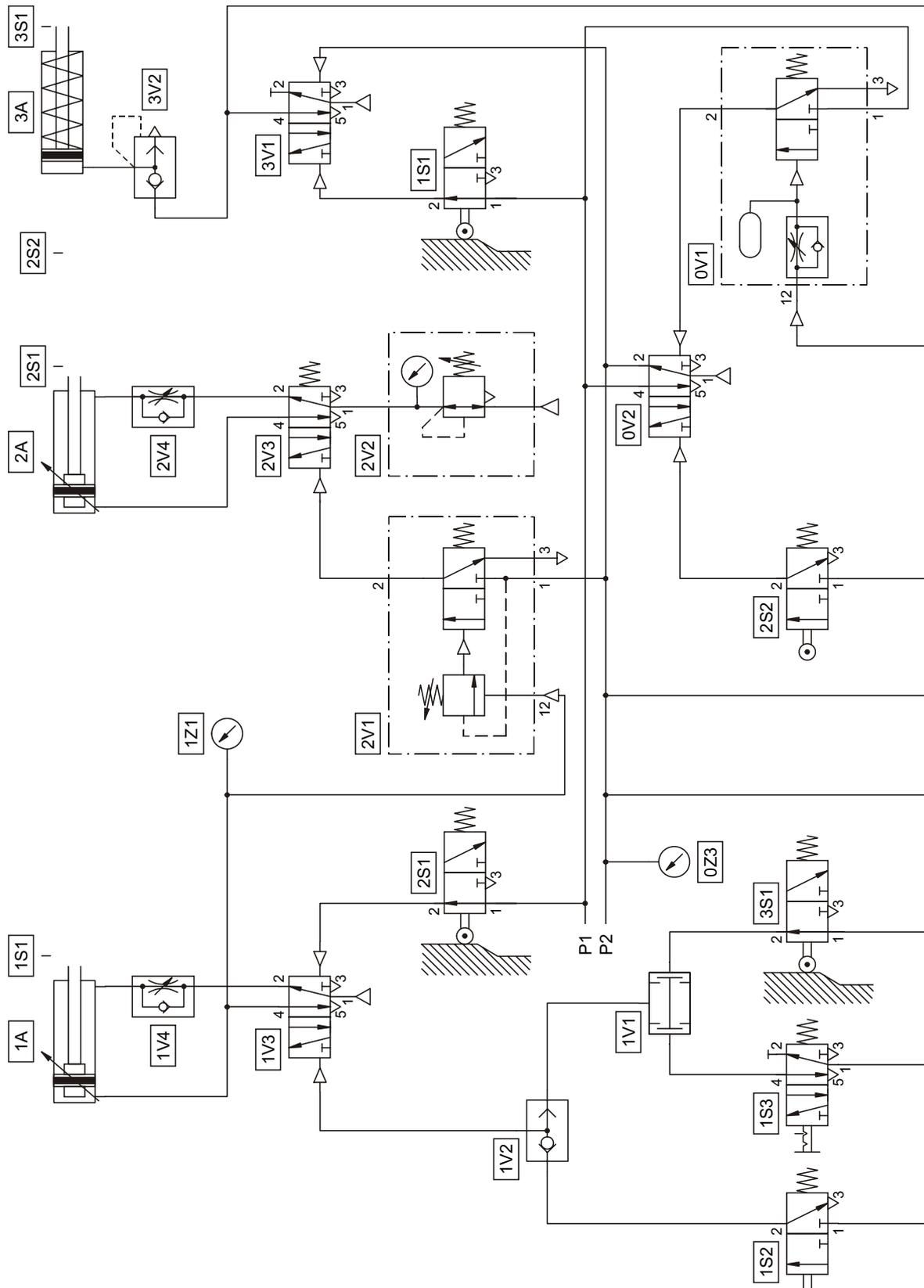
Step 6-7

When time delay valve (0V1) has been switched through, the ejector cylinder (3A) returns quickly. The fast movement is achieved by the use of a quick exhaust valve (3V2). In the retracted end position, ejecting cylinder (3A) actuates roller lever valve (3S1). When the 5/2-way valve with selector switch (1S3) has been switched, a new cycle is initiated.

Continuous cycle / single cycle

When the valve with selector switch (1S3) is in the position shown, a start signal with the push button (1S2) initiates a single cycle. A continuous cycle is also initiated by reversing the 5/2-way valve with selector switch (1S3). If the detented valve is reset, the controller remains in the initial position at the end of the cycle.

Fig. 19/5: Circuit design A



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Solution 19

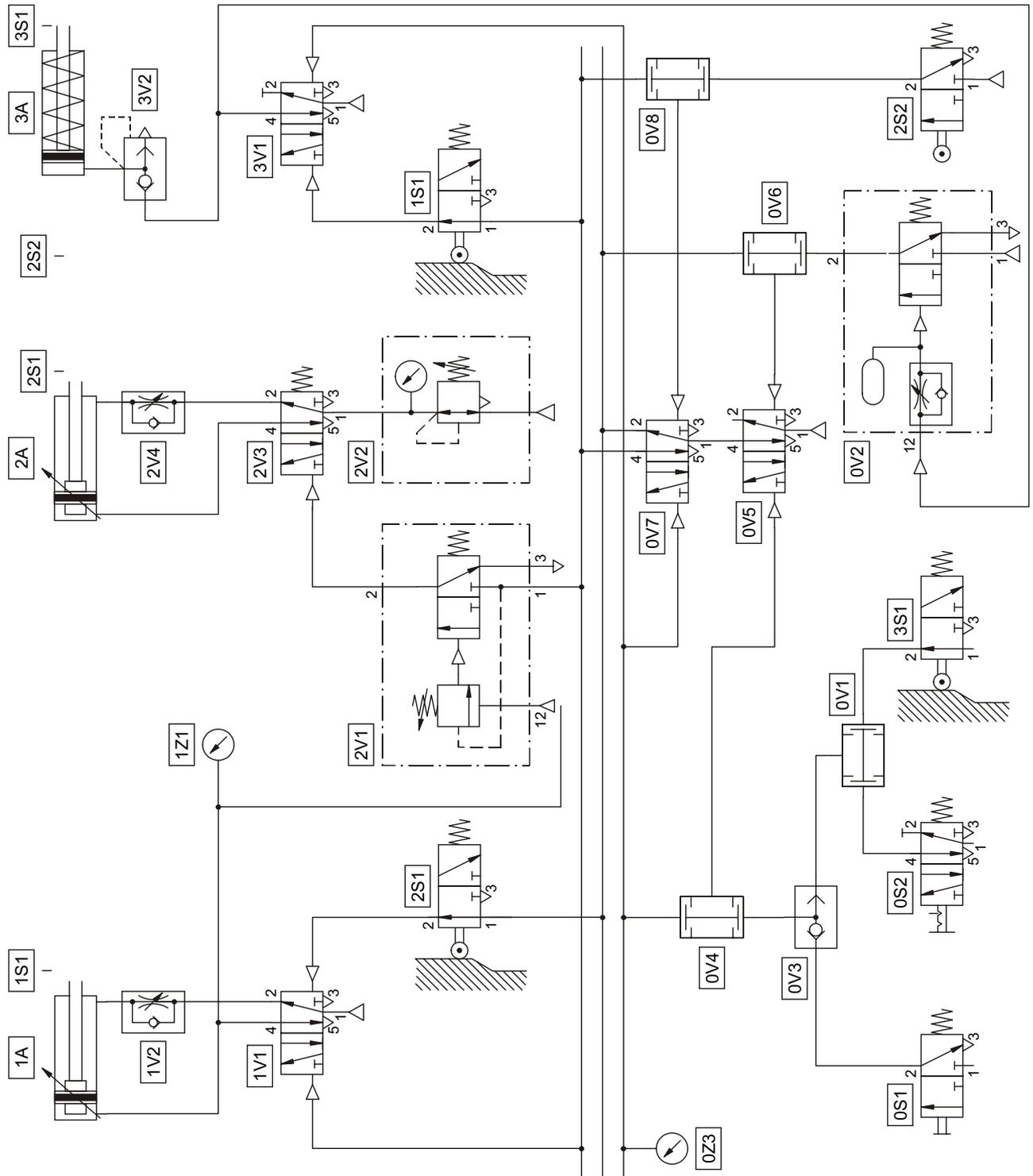
<i>Components list</i>	<i>Components</i>	<i>Description</i>
	0V1	Time delay valve, normally closed
	0V2	5/2-way double pilot valve
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	0Z3	Pressure gauge
	1A	Double-acting cylinder
	1S1	3/2-way roller lever valve, normally closed
	1S2	3/2-way valve with push-button, normally closed
	1S3	5/2-way valve with selector switch
	1V1	Dual-pressure valve
	1V2	Shuttle valve
	1V3	5/2-way double pilot valve
	1V4	One-way flow control valve
	1Z1	Pressure gauge
	2A	Double-acting cylinder
	2S1	3/2-way roller lever valve, normally closed
	2S2	3/2-way roller lever valve, normally closed
	2V1	Pressure sequence valve
	2V2	Pressure regulator with pressure gauge
	2V3	5/2-way single pilot valve
	2V4	One-way flow control valve
	3A	Single-acting cylinder
	3S1	3/2-way roller lever valve, normally closed
	3V1	5/2-way double pilot valve
	3V2	Quick exhaust valve

- Follow up* ■ Construct alternative circuit B. What advantages are offered by division into three rather than two groups?

Abbreviated notation With division into groups for alternative circuit B

1A+	2A+	2A-	1A-	3A+	3A-
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Fig. 19/6:
Alternative circuit B
Circuit design

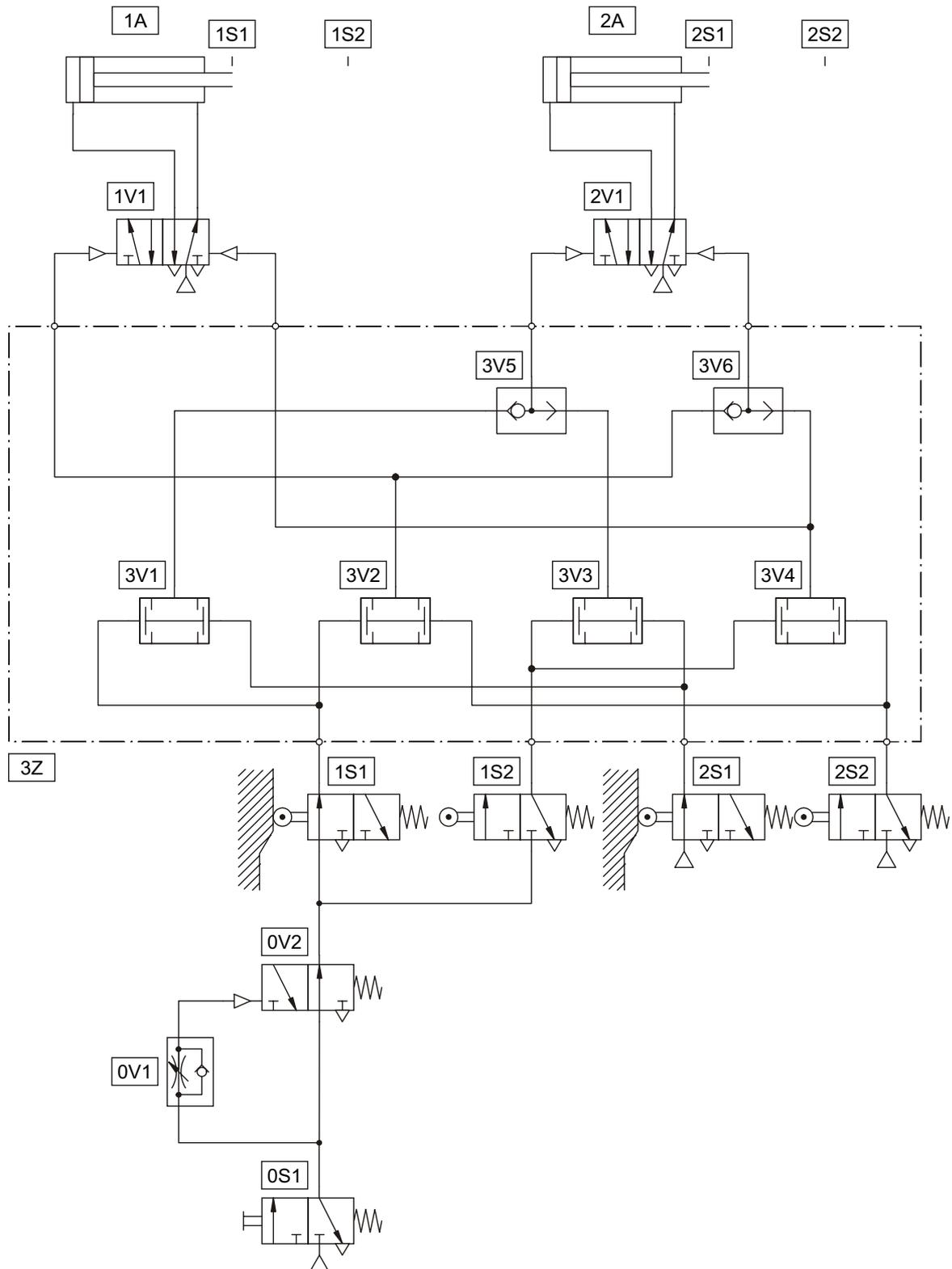


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Solution 19

Pneumatic Counter

Fig. 20/2: Circuit diagram

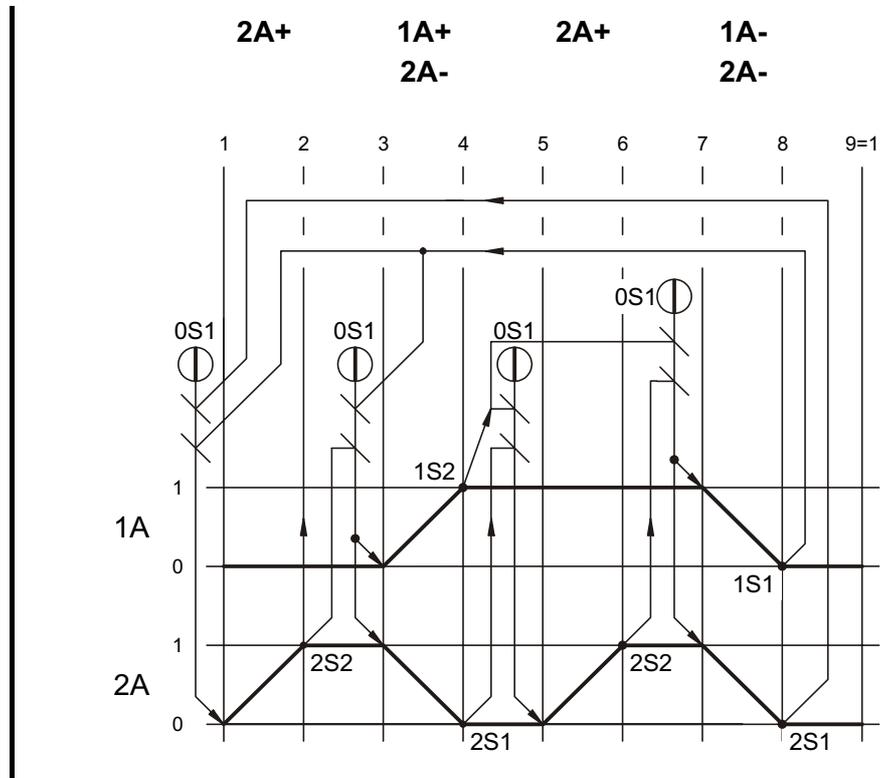


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Solution 20

Abbreviated notation

Fig. 20/3: Displacement-step diagram



Solution description

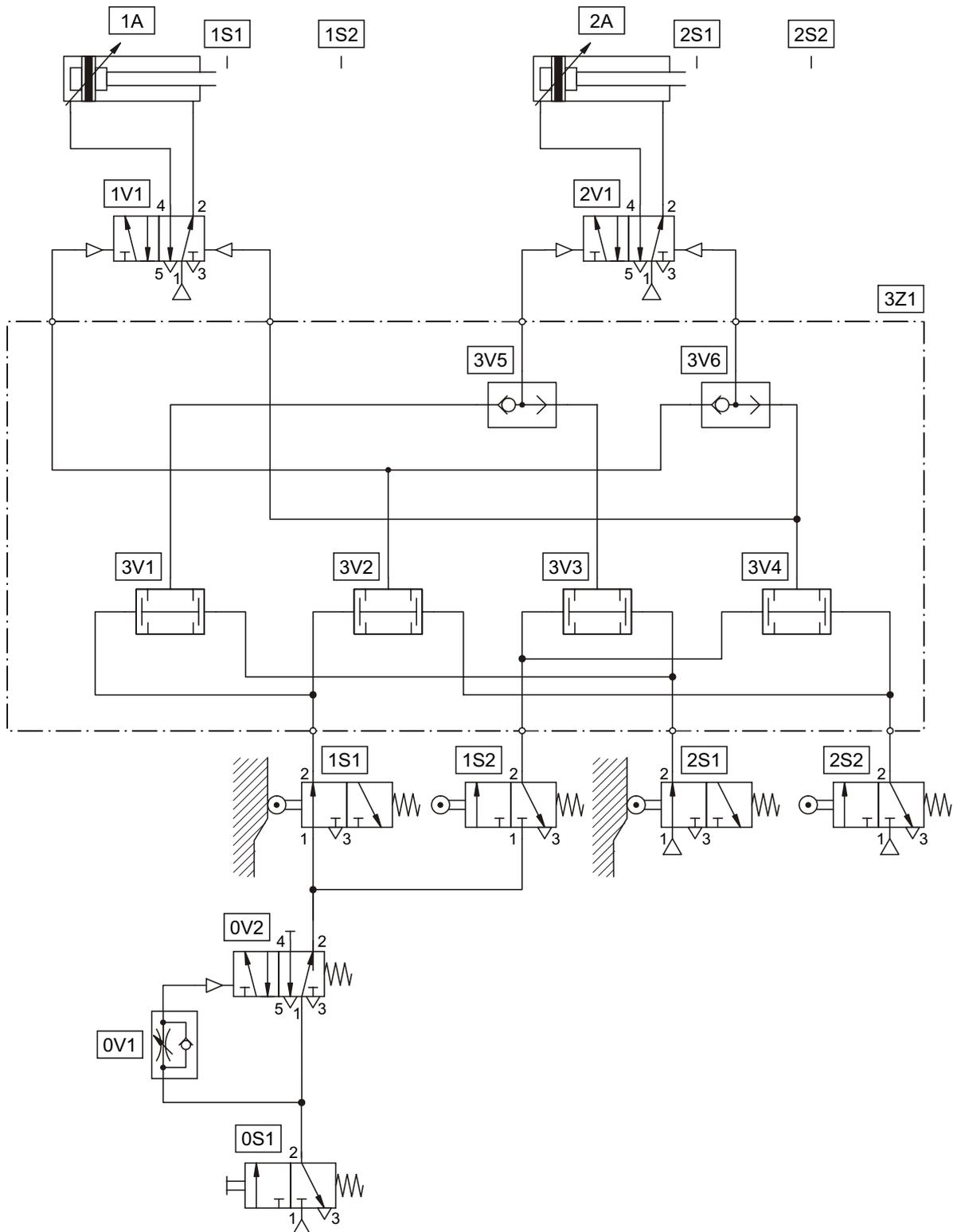
When a counting process has been completed, i. e. the cylinders have carried out their movements, one roller lever valve is always actuated per cylinder. The signal to continue counting (counting signal) need, therefore, only be given to roller lever valves (1S1) and (1S2).

Cylinder (1A) represents the left figure (2^1) in the binary system, whilst a counting cycle (1,2,3,0) reverses the final control element (1V) twice. The dual-pressure valve (3V2) signals to the final control valve (1V) to extend. The dual-pressure valve (3V4) signals in the same way to the same valve to retract.

Cylinder (2A) represents the right-hand figure (2^0) in the binary system whilst a counting cycle switches the final control element (2V) four times. The two shuttle valves (3V5) and (3V6) process together these four signals for the final control valve (2V).

- Dual-pressure valve (3V1) counts from zero to one.
- Dual-pressure valve (3V2) counts from one to two.
- Dual-pressure valve (3V3) counts from two to three.
- Dual-pressure valve (3V4) counts from three to zero.

Fig. 20/4: Circuit design



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Solution 20

Components list	Components	Description
	0S1	3/2-way valve with push button, normally closed
	0V1	One-way flow control valve
	0V2	5/2-way single pilot valve
	0Z1	Service unit with on-off valve
	0Z2	Manifold
	1A	Double-acting cylinder
	1S1	3/2-way roller lever valve, normally closed
	1S2	3/2-way roller lever valve, normally closed
	1V1	5/2-way double pilot valve
	2A	Double-acting cylinder
	2S1	3/2-way roller lever valve, normally closed
	2S2	3/2-way roller lever valve, normally closed
	2V1	5/2-way double pilot valve
	3V1	Dual pressure valve
	3V2	Dual pressure valve
	3V3	Dual pressure valve
	3V4	Dual pressure valve
	3V5	Shuttle valve
	3V6	Shuttle valve

- Follow up*
- Replace the signal input arrangement (0S), (0V1) and (0V2) with a pulse oscillator with the signal frequency $f = 1/3$ Hz (Hertz), which counts continually. Specifications for the pulse oscillator:
 - Pneumatic self-latching with “dominant off behaviour”
 - Time delay valve
 - Dual pressure and shuttle valves



Fig. 20/5: The cylinder (2A) carries out a double movement for each cycle. In the case of the cascade control, 3 reversing valves are necessary (see exercise 18).

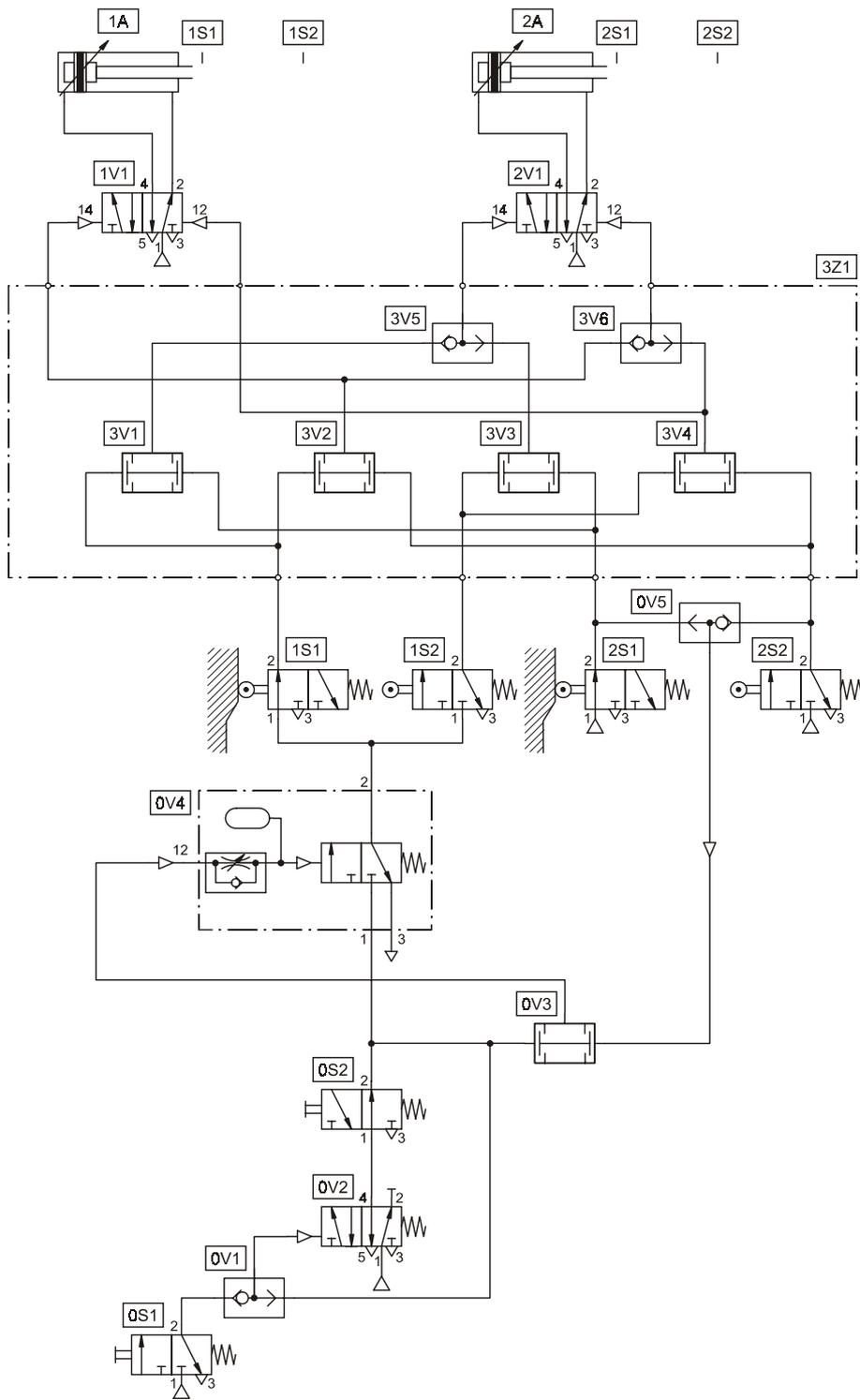


Fig. 20/5: Follow up
Circuit design solution

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Solution 20