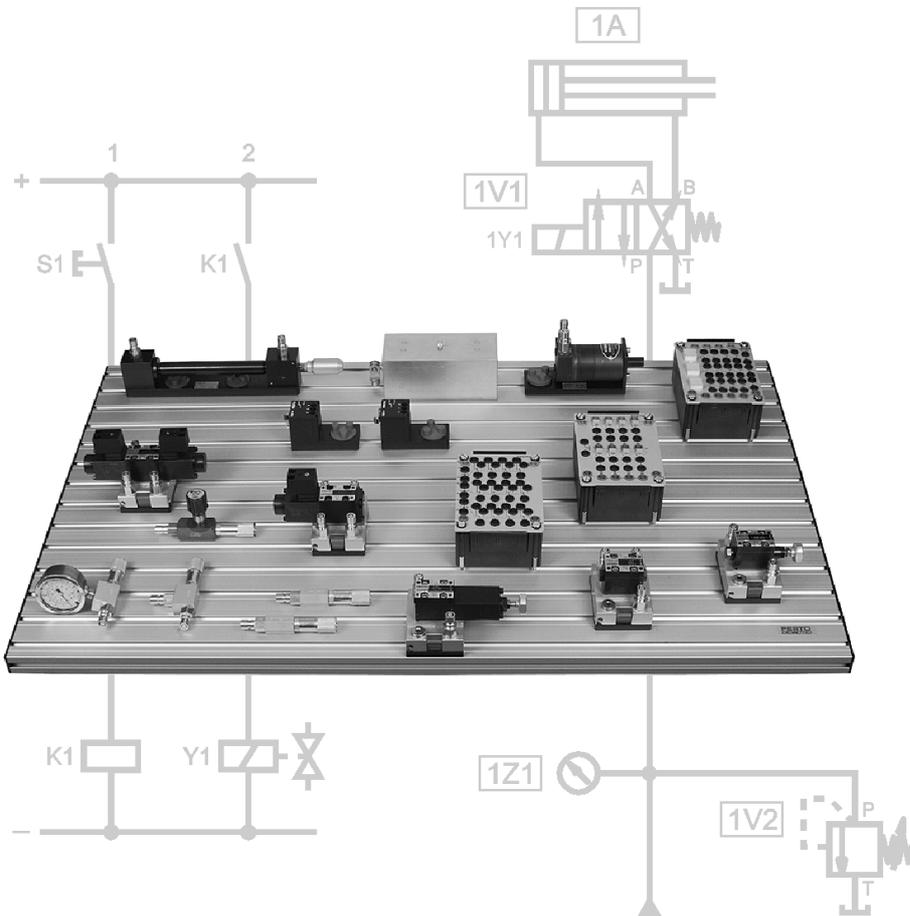


Electrohydraulics

Workbook Basic Level



FESTO

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| | |
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Preface

Festo Didactic's Learning System for Automation and Communications is designed to meet a number of different training and vocational requirements. The Training Packages are structured accordingly:

- Basic Packages provide fundamental knowledge which is not limited to a specific technology.
- Technology Packages deal with the important areas of open-loop and closed-loop control technology.
- Function Packages explain the basic functions of automation systems.
- Application Packages provide basic and further training closely oriented to everyday industrial practice.

Technology Packages deal with the technologies of pneumatics, electropneumatics, programmable logic controllers, automation with PCs, hydraulics, electrohydraulics, proportional hydraulics and application technology (handling).

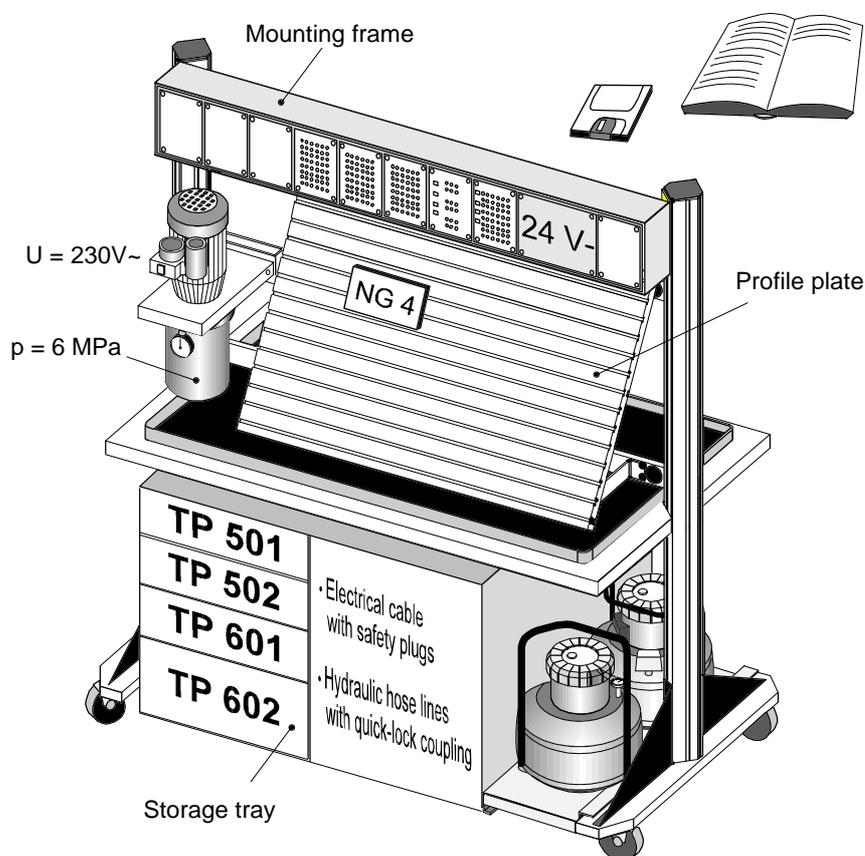


Fig. 1
Example of
Hydraulics 2000:
Mobile laboratory trolley

The modular structure of the Learning System permits applications to be assembled which go beyond the scope of the individual packages. It is possible, for example, to use PLCs to control pneumatic, hydraulic and electrical actuators.

All training packages have an identical structure:

- Hardware
- Courseware
- Software
- Courses

The hardware consists of industrial components and installations, adapted for didactic purposes.

The courseware is matched methodologically and didactically to the training hardware. The courseware comprises:

- Textbooks (with exercises and examples)
- Workbooks (with practical exercises, explanatory notes, solutions and data sheets)
- OHP transparencies, electronic transparencies for PCs and videos (to bring teaching to life)

Teaching and learning media are available in several languages. They have been designed for use in classroom teaching but can also be used for self-study purposes.

In the software field, CAD programs, computer-based training programs and programming software for programmable logic controllers are available.

Festo Didactic's range of products for basic and further training is completed by a comprehensive selection of courses matched to the contents of the technology packages.

Latest information about the technology package **TP601**.

New in Hydraulic 2000:

- Industrial components on the profile plate.
- Exercises with exercise sheets and solutions, leading questions.
- 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 Festo Didactic's Learning System for Automation and Communications. The Training Package TP 600 is designed to provide an introduction to the fundamentals of electrohydraulic control technology. This package comprises a basic level and an advanced level. The basic level package TP 601 teaches basic knowledge of electrohydraulic control technology. The equipment sets TP 601 and TP 602 (for the advanced level) provide the student with the key qualification "Technical competence".

The hydraulic components have been designed to provide the following:

- Easy handling
- Secure mounting
- Environmentally-friendly coupling system
- Compact component dimensions
- Authentic measuring methods

You will require the following for the practical execution of the exercises:

- A Festo Didactic profile plate or a laboratory trolley
- An equipment set TP 601 (cylinders, valves, relay plate, ...)
- A hydraulic power pack
- A number of hydraulic hose lines
- An electrical power supply unit
- A set of electrical cables

The Training Package TP 601 specifies fundamental training contents. These help develop both technical and methodological competence in electrohydraulics:

- Physical interrelationships in electrical engineering and hydraulics
- Drafting, assembly and understanding of basic electrohydraulic circuits
- Comparison of the use of various valves and other components
- Development of alternative solutions

The technical requirements for safe operation of the components are as follows:

- A hydraulic power pack to provide an operating pressure between 0.5 and 6 Mpa (5 to 60 bar) and a flow rate of 2 l/min.
- An electrical power supply for the above of 230 V AC, 50 Hz, with a 10 A fuse.
- A short-circuit-proof electrical power supply for the electrical components with an output of 24 V DC and a 3 A fuse.
- A profile plate to mount the components
The profile plate (1100 x 700 mm) has 14 parallel T-grooves at intervals of 50 mm.

This workbook has been developed for use in the “Dual system” of vocational training. It is, however, equally suitable for use in providing a practical introduction to electrohydraulics for students at universities and technical colleges. The modular design of the hardware allows theoretical questions to be dealt with experimentally in a simple and efficient form.

The theoretical background to facilitate understanding of this workbook is provided in the textbook

Learning System for Automation and Communications

■ **Electrohydraulics** Basic Level

Festo Didactic also offers the following further training materials for hydraulics:

- Sets of OHP transparencies and electronic transparencies for PCs
- Linear videos and interactive videos (video discs)
- Autosketch CAD software and symbol library
- Hydraulics simulation program for planning, simulation and visualisation (in course of preparation)
- Sets of magnetic symbols and symbols for OHPs, hydraulic slide rule
- Transparent models for OHPs, with special hydraulic power pack
- Equipment sets: BIBB, hand-lever hydraulics, proportional hydraulics, closed-loop hydraulics, measurement kit in case

Please see our special brochures for a detailed description of further training materials.

Notes on safety



Observe the following in the interests of your own safety:

- **Caution!**
Cylinders may move unexpectedly when the hydraulic power pack is switched on.
- Do not exceed the maximum permissible hydraulic operating pressure. See the relevant data sheets.
- Do not operate electrical limit switches directly by hand when carrying out fault-finding. Use a tool for this.
- Use only an extra-low voltage of 24 V to operate the components.
- Observe all general safety instructions.



Notes on operation

Assembly

Always work in the following sequence when assembling or dismantling an electrohydraulic circuit.

1. The hydraulic power pack and electrical power supply must be switched off during the assembly of the circuit.
2. All components must be securely fitted to the profile plate or mounting frame.
3. Connect up the hydraulic hose lines.
All valves, other components and hose lines are fitted with self-closing quick-acting couplings. Do not exceed the maximum permissible pressure of 12 MPa (120 bar). The maximum operating pressure is 6 MPa (60 bar).
4. Connect up the electrical cables.
Connect test leads to the component sockets by means of 4 mm plugs.
5. Before commissioning a hydraulic control circuit, check that all return lines are connected and that all connectors are secure.
6. Switch on the electrical power supply first and then the hydraulic power pack.
7. Commissioning the control circuit
 - Press the START pushbutton
 - Set components, etc.
 - Compare what you have assembled with the description in the book.

Dismantling

8. Before dismantling the circuit, ensure that pressure in hydraulic components has been released:

Couplings must be disconnected only under zero pressure!

9. Switch off the hydraulic power pack first and then the electrical power supply.

Technical notes

Observe the following in order to ensure safe operation.

- The hydraulic power pack incorporates an adjustable pressure relief valve. In the interests of safety, the pressure is limited to approx. 6 MPa (60 bar). Every time a control circuit is assembled on the profile plate, a second pressure relief valve is used. We recommend that this should be set to a maximum pressure of 5 MPa (50 bar).
- All valves, cylinders and hose lines are fitted with quick-acting couplings which ensure minimum leakage. The maximum pressure for all components in the training package is 12 MPa (120 bar). Thanks to their design, the couplings reduce leakage during connection and disconnection to a minimum.

The operating pressure should not exceed 6 MPa (60 bar)

- In the case of double-acting cylinders, the pressure intensification effect may produce an increased pressure proportional to the area ratio of the cylinder. With an area ratio of 1:1.7 and an operating pressure of 6 MPa (60 bar), this increased pressure may be over 10 MPa (100 bar)!

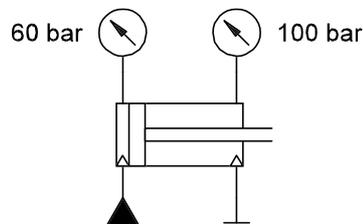


Fig. 2:
Pressure intensification

- If connections are detached under pressure, the non-return valve in the coupling may cause pressure to become trapped in the valve or other component concerned. The pressure relief device can be used to release this pressure. Exception: This is not possible in the case of hose lines and non-return valves. Ensure therefore that control circuits are depressurised before hose lines are disconnected and the circuit is dismantled.
- All valves, other components and hose lines are fitted with self-closing quick-acting couplings. This prevents the accidental spillage of hydraulic fluid. In the interests of simplicity, these couplings are not shown in circuit diagrams.

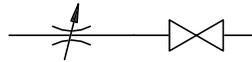
Fig. 3:
Simplified representation
in circuit diagrams



Throttle

Hose

Shut-off valve



Symbolic representation of directional control valves

Valves are shown in the “Circuit diagram, hydraulic” in essentially the same way as in the textbook. The crossover position is on the right and the parallel position on the left. Working port A is, however, on the right, and port B is therefore on the left. This symbolic representation conforms to the new “Hydraulics 2000” hardware.

The drawing “Practical assembly, hydraulic” is based on the symbol on the valve. The crossover position is on the left and the parallel position on the right. Working port A is now on the left and port B on the right. This symbolic representation is hardware-oriented.

The two different symbolic representations describe all functions of a given valve. In practice, valves by different manufacturers with identical functions are sometimes given different symbols. This is permitted by the applicable standard, DIN ISO 1219 Part 1, of November 1993 with the title “Fluidics: Graphic Symbols and Circuit Diagrams”.

| | <i>Circuit diagram, hydraulic</i> | <i>Practical assembly, hydraulic</i> | <i>Representation of directional control valves</i> |
|--|-----------------------------------|--------------------------------------|---|
| 4/2-way solenoid valve | | | |
| 4/3-way solenoid valve in mid-position | | | |

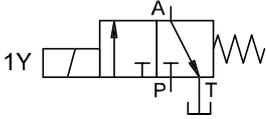
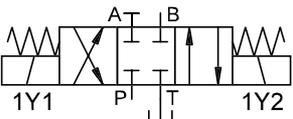
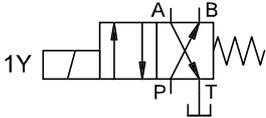
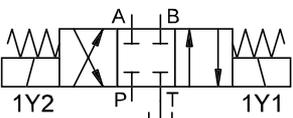
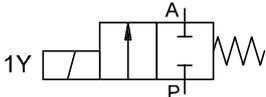
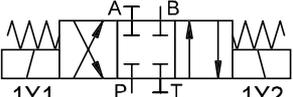
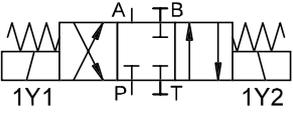
Since hydraulic valves are very expensive, only a small number of these and only a small number of different types are used in the equipment set.

The 4/2-way valve can be used to produce four further basic functions.

| | <i>Basic function in "Circuit diagram, hydraulic"</i> | <i>Connection of 4/2-way solenoid valve in "Practical assembly, hydraulic"</i> |
|---|---|--|
| 2/2-way valve with closed in neutral position | | |
| 2/2-way valve with flow in neutral position | | |
| 3/2-way valve with closed in neutral position | | |
| 3/2-way valve with flow in neutral position | | |

Ports on the directional control valve which are not required are sealed by the self-closing coupling nipples. It is not necessary to seal these ports by means of plugs.

The 4/3-way valve with closed mid-position fulfils various different functions in the exercises in this book.

| | <i>Function of solenoid valves in "Circuit diagram, hydraulic"</i> | <i>Connection of 4/3-way solenoid valve in "Practical assembly, hydraulic"</i> |
|---|--|---|
| No electrical connection is made to solenoid 1Y2 |  |  |
| Solenoid 1Y2 must be activated in "Practical assembly, electrical" via an additional path. |  |  |
| No electrical connection is made to solenoid 1Y2. or No electrical connection is made to solenoid 1Y1 |  |  |
| | |  |

Electrical

Power supply:
230 VAC, 50 Hz

- The hydraulic power pack is protected by a 10 A fuse.
- The short-circuit proof electrical power supply has a 3 A fuse.
- The output voltage of this power supply is 24 V DC.
- The output current is limited to a maximum of 4.5 A.

Wiring:

Universal cable set: 61 red and 37 blue laboratory cables in 5 lengths. All electrohydraulic components are equipped with 4 mm sockets. The electrical connections for these components are made using the laboratory cables with 4 mm plugs.

A distinction should be made between the two designs of electrical limit switches:

- Electrical limit switch, actuated from the **left**.
- Electrical limit switch, actuated from the **right**.
- When cylinder piston speeds are high, the limit switches should be actuated by cylinder cams only in the specified direction.
- Limit switches must not be actuated from the front.
- Both types of limit switches are shown by the same symbol in the hydraulic and electrical circuit diagrams.

Training contents

- Basic physical principles of electrical engineering and hydraulics
 - Function and use of electrical and electrohydraulic components such as switches, pushbuttons and solenoid valves
 - Naming and identifying electrical and hydraulic symbols
 - Development and reading of standard circuit diagrams
 - Representation of control exercises as function diagrams
 - Drafting, assembly and commissioning of basic circuits
 - Direct and indirect activation of cylinders
 - Activation of a hydraulic motor
 - MANUAL and AUTOMATIC modes
 - Position and pressure dependent control circuits
 - Interlock circuit
 - Rapid-traverse circuit
 - Fault-finding with simple electrohydraulic control circuits
- Basic Level
(TP601)*
-
- Function and use of electronic sensors, hydraulic motors and hydraulic accumulators
 - Complex sequence controls
 - Combination position and pressure dependent control circuits
 - Electrical control circuit with several actuators
 - Sequence controls with MANUAL/AUTOMATIC, EMERGENCY STOP and SETTING modes
 - Circuit with hydraulic accumulator
 - Position and time dependent control circuits
 - Systematic fault-finding in electrohydraulic control circuits
 - Development of sequence controls from a function diagram
 - Controls with timer relays with pick-up and drop-off delays
 - Counter controls with predetermining counters
- Advanced Level
(TP602)*

Training aims/exercise table (Table 1)

List of training aims

| Training aims | Exercise | | | | | | | | | | | | |
|--------------------------------------|----------|---|---|---|---|---|---|---|---|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Actuation of double-acting cylinders | • | • | | • | • | • | • | • | • | • | • | • | • |
| Actuation of single-acting cylinders | | | • | | | | | | | | | | |
| Actuation of a hydraulic motor | | | | | | | | | | | | • | |
| Direct actuation | • | | | | | | | | | | | | |
| Indirect actuation | | • | • | • | • | • | • | • | • | • | • | • | • |
| Control circuit operated manually | • | • | • | | | | | | | | | | |
| Control circuit with latching | | | | • | • | | | | | | | | |
| Use of a pressure switch | | | | | • | | | | | • | | • | |
| Production of a differential circuit | | | | | | • | | • | | | | | |
| Interlock circuit | | | | | | | • | | | | | | |
| INCHING operation | | | | | | | • | | | | | | |
| Use of limit switches | | | | | | | | • | • | • | • | • | • |
| Rapid-traverse feed circuit | | | | | | | | | • | • | | | |
| Pressureless pump bypass | | | | | | | | | | | | • | |

Equipment set for Basic Level TP 601

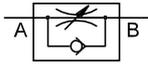
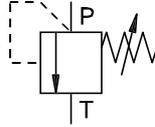
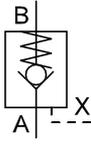
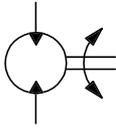
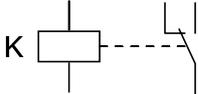
This equipment set has been compiled for use in basic training in electrohydraulic control technology. The set can be combined in any desired way with other equipment sets from the Festo Didactic Learning System.

| <i>Description</i> | <i>Order No.</i> | <i>Qty.</i> |
|---|------------------|-------------|
| Pressure gauge | 152841 | 3 |
| One-way flow control valve | 152843 | 1 |
| Non-return valve, 1 bar | 152845 | 1 |
| Non-return valve, 5 bar | 152846 | 1 |
| Branch tee | 152847 | 8 |
| Pressure relief valve, pressure sequence valve | 152848 | 2 |
| 2-way flow control valve | 152851 | 1 |
| Non-return valve, piloted | 152852 | 1 |
| Double-acting cylinder, 16/10/200 | 152857 | 1 |
| Hydraulic motor, 8 l/min | 152858 | 1 |
| Loading weight, 9 kg | 152972 | 1 |
| Relay, 3-fold* | 162241 | 2 |
| Signal input unit, electrical* | 162242 | 1 |
| Indicator and distributor unit, electrical * | 162244 | 1 |
| 4/2-way solenoid valve | 167082 | 1 |
| 4/3-way solenoid valve closed in mid-position | 167083 | 1 |
| Limit switch, electrical, actuated from the right | 183322 | 2 |
| Limit switch, electrical, actuated from the left | 183345 | 2 |
| <i>We recommend</i> | <i>Order No.</i> | <i>Qty.</i> |
| Hose line with quick-release coupling, 600 mm | 152960 | 10 |
| Hose line with quick-release coupling, 1000 mm | 152970 | 8 |

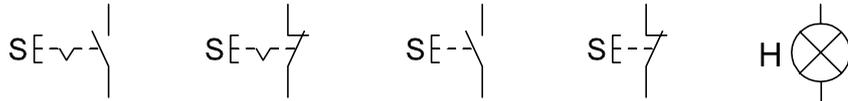
Order No.: 184463 for equipment set TP 601

* These components can be mounted in the mounting frame or, by using the adapter set (Order No. 35651), on the profile plate.

*Symbols for
equipment set TP 601*

| | |
|--|---|
| <p>Pressure gauge</p>  | <p>One-way flow control valve</p>  |
| <p>Non-return valve, 1 bar resp. 5bar</p>  | <p>Pressure relief valve, pressure sequence valve</p>  |
| <p>2-way flow control valve</p>  | <p>Non-return valve, piloted</p>  |
| <p>Double-acting cylinder, 16/10/200</p>  | <p>Hydraulic motor, 8 l/min</p>  |
| <p>Weight, 9 kg</p>  | <p>Relay, 3-fold</p>  |

Signal input unit, electrical



Symbols for equipment set TP 601

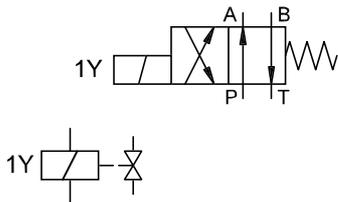
Indicator and distributor unit, electrical



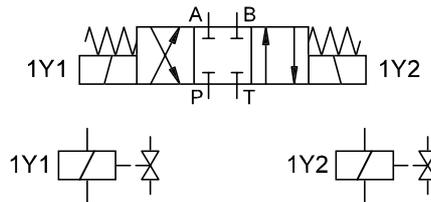
Limit switch, electrical, actuated from the left or from the right



4/2-way solenoid valve



4/3-way solenoid valve closed in mid-position



Equipment set for Advanced Level TP 602

This equipment set has been compiled for advanced-level teaching of electrohydraulic control technology. The two equipment sets TP 601 and TP602 can be expanded in any desired way with other equipment sets from Festo Didactic's Learning System for Automation and Communications.

Order No.: 184464
for equipment set TP 602

| <i>Description</i> | <i>Order-No.</i> | <i>Qty.</i> |
|--|------------------|-------------|
| Relay, 3-fold* | 162241 | 2 |
| Timer relay, 2-fold* | 162243 | 1 |
| Predetermining counter, electrical, additive * | 162355 | 1 |
| Indicator and distributor unit, electrical * | 162244 | 1 |
| Pressure switch | 167080 | 1 |
| Branch tee | 152847 | 4 |
| Pressure relief valve, piloted | 152849 | 1 |
| 3-way pressure reducing valve | 152850 | 1 |
| 4/2-way solenoid valve | 167082 | 1 |
| Double-acting cylinder, 16/10/200 | 152857 | 1 |
| Diaphragm accumulator with shut-off block | 152859 | 1 |
| EMERGENCY STOP, electrical | 183347 | 1 |
| Proximity switch, inductive | 178574 | 1 |
| Proximity switch, capacitive | 178575 | 1 |
| Proximity switch, optical | 178577 | 1 |

| <i>We recommend:</i> | <i>Order-No.</i> | <i>Qty.</i> |
|--|------------------|-------------|
| Hose line with quick-release coupling, 600 mm | 152960 | 10 |
| Hose line with quick-release coupling, 1000 mm | 152970 | 2 |

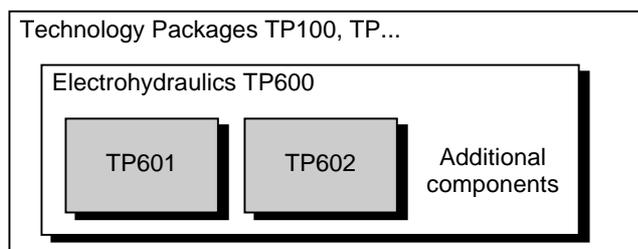
* These components can be mounted in the mounting frame or, by using the adapter set (Order No. 35651), on the profile plate.

List of additional components for TP600

| Description | Order-No. |
|--|-----------|
| Extension kit for hydraulic cylinder | 120778 |
| Throttle valve | 152842 |
| Shut-off valve | 152844 |
| Hose line with quick-release coupling, 600 mm | 152960 |
| Power pack, hydraulic, 2 l/min | 152962 |
| Hose line with quick-release coupling, 1000 mm | 152970 |
| Pressure relief device | 152971 |
| Cover (for loading weight, 9 kg) | 152973 |
| Hose line with quick-release coupling, 1500 mm | 158352 |
| Hose line with quick-release coupling, 3000 mm | 159386 |
| Power supply unit, attachment fixture, 24V 4.5A, Deutsch | 159396 |
| Profile plate, large | 159411 |
| Set of labels, Hydraulics | 162383 |
| Power supply unit, table, 24V 4.5A, Deutsch | 162417 |
| Flow rate / rotary speed measuring device | 167081 |
| 4/3-way solenoid valve with relieving mid-position | 167084 |
| 4/3-way solenoid valve with recirculating mid-position | 167085 |
| Cable set with safety plugs | 167091 |
| Coupling nipple | 342047 |
| Coupling socket | 346491 |

For further additional components from our "Hydraulics 2000" system, please see our price lists.

Learning System for Automation and Communications



Component/exercise table (Table 2)

| Description | Exercise | | | | | | | | | | | | |
|---|----------|---|---|---|---|---|---|---|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Relay, 3-fold | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Signal input unit, electrical | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Indicator and distributor unit, electrical | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Pressure gauge | | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 2 |
| One-way flow control valve | | 2 | 1 | | | | 1 | | | 1 | | 1 | 2 |
| Non-return valve, 1 bar | | | | | | | | | 1 | | | | |
| Non-return valve, 5 bar | | | | | | | | | | | | 1 | |
| Pressure relief valve, pressure sequence valve | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| 2-way flow control valve | | | | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | | |
| Non-return valve, piloted | | | | | | | 1 | | | | | 1 | |
| 4/2-way solenoid valve | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| 4/3-way solenoid valve with closed in mid-position | | | | | | | 1 | 1 | 1 | 1 | | 1 | 1 |
| Double-acting cylinder 16/10/200 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Hydraulic motor, 8 l/min | | | | | | | | | | | | | |
| Limit switch, electrical, actuated from the left | | | | | | | | 1 | 1 | | 1 | | 2 |
| Limit switch, electrical, actuated from the right | | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 |
| Loading weight | | | 1 | | | | | | | | | | |
| Branch tee | | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 7 | 4 | 4 | 5 | 4 |
| Hose line with quick-release coupling, 600 or 1000 mm | 4 | 5 | 7 | 7 | 7 | 7 | 9 | 9 | 11 | 11 | 8 | 12 | 12 |

For exercises 5, 10 and 11 a pressure switch of the equipment set TP 602 is required. For exercise 13 you will need another double-acting cylinder.

Methodological structure of exercises

All 13 exercises have the same methodological structure.

- The exercises in Part A are structured as follows:
 - Subject
 - Title
 - Training aim(s)
 - Exercise
 - Problem definition
 - Positional sketch

A worksheet then follows for use in carrying out the exercise:

- The suggested solutions in Part C are structured as follows:
 - Circuit diagram, hydraulic-
 - Circuit diagram, electrical
 - Solution description with evaluation and conclusions
 - Practical assembly, hydraulic
 - Practical assembly, electrical
 - Components list, hydraulic
 - Components list, electrical
- How should I work through an exercise?
 - Read the worksheet
 - Complete the worksheet
 - Assemble and commission the control circuit
 - Work out your own solution
 - Compare your solution with the one in this book
 - Incorporate your solution into the control circuit
 - Commission this circuit
 - Does your control circuit fulfil the requirements specified in the-worksheet?