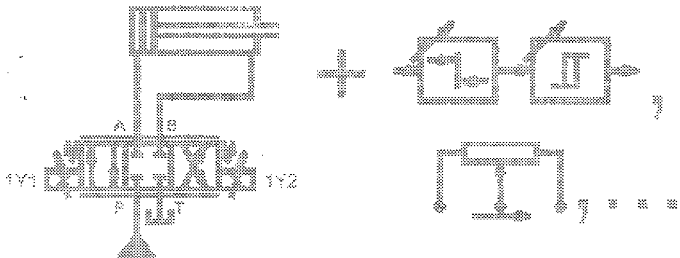
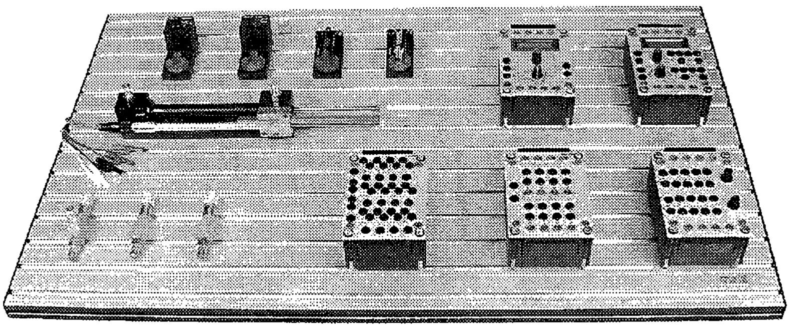
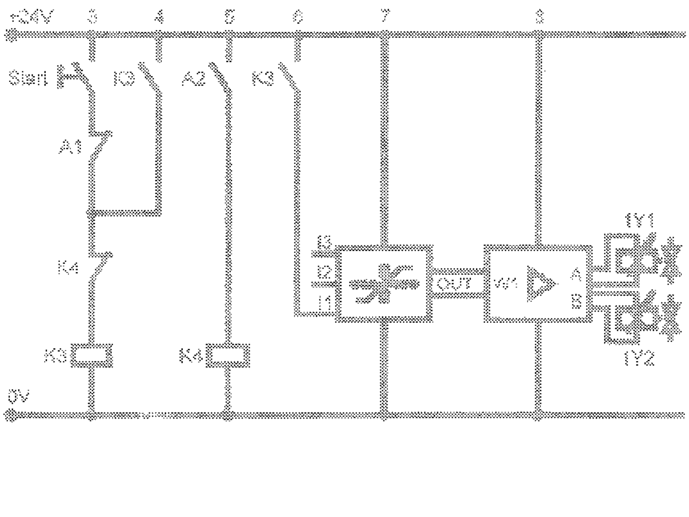
Learning System for Automation

Proportional-hydraulics

Workbook Advanced Level







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Authorised applications and liability

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

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

Order No.:	094473
Description:	TEACHW. P-HYDR.
Designation:	D.S702-C-SIBU-GB
Edition:	08/1999
Layout:	06.08.1999, OCKER Ingenieurbüro
Graphics:	D. Schwarzenberger
Author:	E. Bauer

Preface

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

- Basic packages deal with basic knowledge spanning a wide range of technologies.
- Technology packages deal with important areas of control technology.
- Function packages explain the basic functions of automation systems.
- Application packages provide basic and further training loosely oriented to everyday industrial practice.

The technology packages deal with the following technologies: Pneumatics, electro-pneumatics, programmable logic controllers, automation using a personal computer, hydraulics, electro-hydraulics, proportional hydraulics and handling technology.

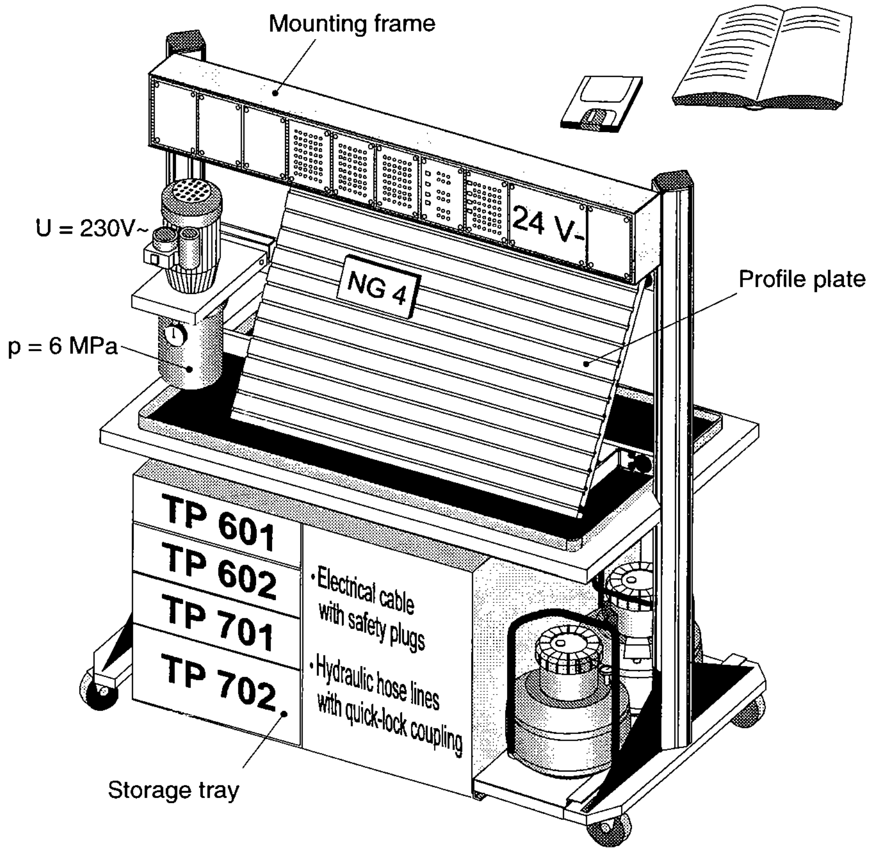

Fig. 1: Example of Hydraulics 2000 – Mobile laboratory trolley

The modular design of the learning system permits applications which go beyond the scope of the individual packages, such as PLC actuation of pneumatic, hydraulic and electrical actuators.

All learning packages are of an identical structure:

- Hardware
- Teachware
- 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 and comprises:

- Textbooks (with exercises and examples)
- Workbooks (with practical exercises, supplementary notes, solutions and data sheets)
- Overhead transparencies and videos (to provide a lively, interactive classroom atmosphere)

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

As far as software is concerned, 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.

Information on the Technology Package "Proportionalhydraulics" TP702

New features of Hydraulics 2000

- All electrical cables with safety plugs.
- Authentic industrial components, nominal size 4 mm, on the profile plate.
- Exercises with exercise sheets and solutions, leading questions.
- Development of key qualifications:
  Technical competence, methodological competence, social competence and personal competence.
- Practice in teamwork, cooperation, study technique, independence and organisational ability.

Objective – **Competence in action**

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Section B – Fundamentals

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Introduction

This workbook forms part of Festo Didactic's Learning System for Automation and Communication. TP700 is intended as an introduction to the fundamentals of proportional hydraulics and consists of a basic level and advanced level. The basic level TP701 provides the basic knowledge on proportional hydraulics, which is consolidated and dealt with in greater depth in the advanced level TP702.

The following points have been included in the design concept of the hydraulic components:

- Simple handling
- Secure attachment
- Environmentally friendly coupling technology
- Compact components
- Practice-oriented measuring technology

The following are recommended for the practical implementation of the exercises:

- Hydraulic and electrical components of equipment sets TP701 and TP702
- A hydraulic power pack
- Several hoses
- A power supply unit
- A set of cables
- A slotted profile plate or corresponding laboratory equipment
- The measuring set with the necessary sensors

The aim of this workbook is to familiarise the student with the equipment and basic circuits of proportional hydraulics. The exercises deal with the following subjects:

- Plotting of characteristic curves of various sensors.
- Use of equipment, valves and sensors.
- Construction of different circuits according to specified flow diagrams.
- Optimum harmonisation of components by means of setting parameters.

The technical prerequisites for the safe operation of components are:

- A hydraulic power pack for an operating pressure of 60 bar and volumetric flow rate of 2 l/min.
- A voltage supply of 230 V AC for the power pack.
- A power supply unit with 24 V D.C. for the electrical components.
- A Festo Didactic slotted profile plate for the attachment of components.

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 correlations are explained in the Proportional Hydraulics textbook, Basic Level TP701. The technical description of the components used can be found in the data sheets in section D of this workbook.

The following additional training material for hydraulics is also available from Festo Didactic:

- Magnetic symbols
- Hydraulic slide calculator
- Set of overhead transparencies
- Set of transparent models
- Interactive video
- Symbols library
- Simulation program

Safety recommendations

The following safety advice must be observed in the interest of your own safety:

- Caution! Cylinders may advance as soon as the hydraulic power is switched on!
- Do not exceed the permissible working pressure (see data sheets).
- Use only extra-low voltage of up to 24V.
- Observe general safety regulations (DIN 58126 and VDE 100).

Notes on procedure

Construction

The following steps are to be observed when constructing a control circuit.

1. The hydraulic power pack and the electrical supply unit must be switched off during the construction of the circuit.
2. All components must be securely attached to the slotted profile plate, i.e. safely latched and securely mounted.
3. Please check that all return lines are connected and all hoses securely connected.
4. Make sure that all cable connections have been established and that all plugs are securely plugged in.
5. First, switch on the electrical power supply unit and then the hydraulic power pack.
6. Make sure that the hydraulic components are pressure relieved prior to dismantling the circuit, since:

   Couplings must be connected unpressurised!

7. First, switch off the hydraulic power pack and then the electrical power supply unit.

Technical notes

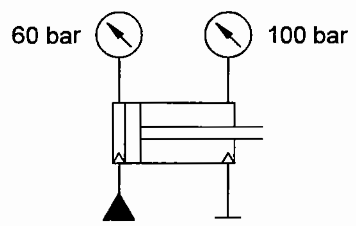
The following notes are to be observed in order to ensure trouble-free operation.

- An adjustable pressure relief valve has been integrated in the hydraulic power pack Part No. 152962. For reasons of safety, the system pressure has been limited to approx. 60 bar (6 MPa).
- The maximum permissible pressure for all hydraulic components is 120 bar (12 MPa).

The working pressure is to be at a maximum of 60 bar (6 MPa).

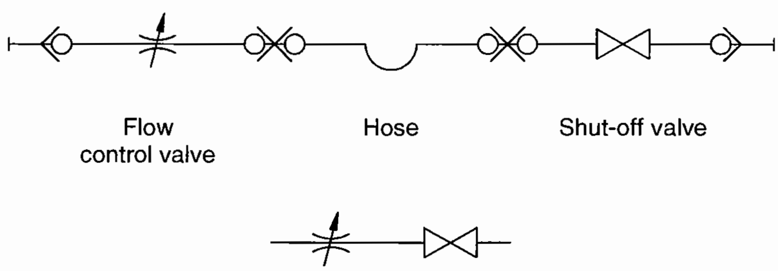
- In the case of double-acting cylinders, an increase in pressure may occur according to the area ratio as a result of pressure transference. With an area ratio of 1:1.7 and an operating pressure of 60 bar (6 Mpa), this may be in excess of 100 bar (10 MPa)!

Fig. 2: Pressure transference



- If the connections are released under pressure, pressure is locked into the valve or device via the non-return valve in the coupling. This pressure can be reduced by means of a pressure relieving device Part No. 152971. Exception: This is not possible in the case of hoses.
- All valves, equipment and hoses have self-sealing couplings. These prevent inadvertent oil spillage. For the sake of simplicity, these couplings have not been represented in the circuit diagram.

Fig. 3: Simplified representation of couplings



Notes on procedure regarding proportional hydraulics

The sample applications for proportional hydraulics given here are based on problems arising in industrial practice.

The technical solutions arrived at correspond to an open control loop system in their method of operation.

Previous knowledge

Knowledge of the fundamentals as provided in the Festo Didactic workbook, TP701 – are a prerequisite.

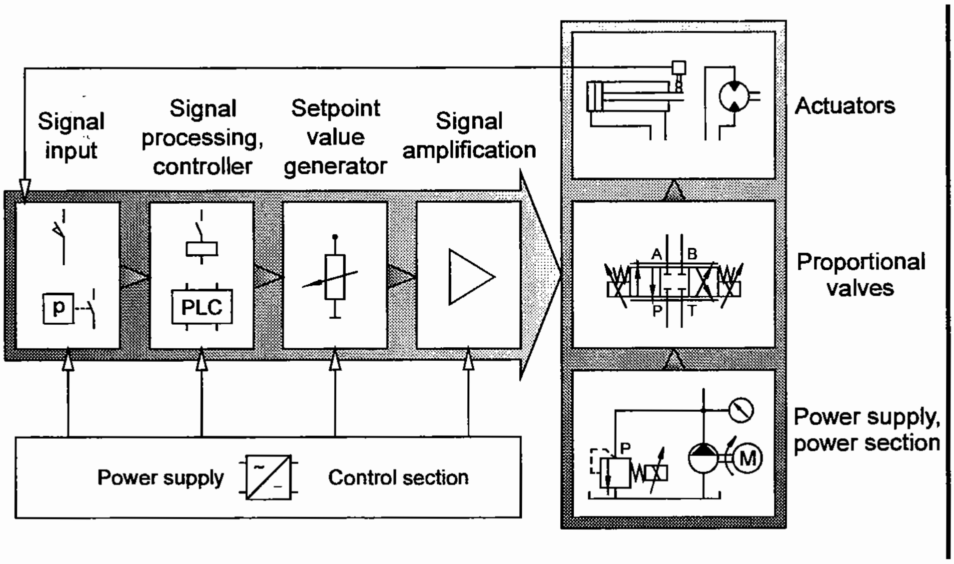


Fig. 4:
System design of proportional hydraulics in an open control loop system

Overall system

To be able to find solutions for problem definitions in proportional technology, the following technologies need to be combined in the system:

- Hydraulics in general
- Proportional valves, control electronics, setpoint generation
- Signal control by means of relay technology and/or PLC
- Signal generator

Power section

In the power section of a proportional hydraulic control system, the hydraulic drive, cylinder and motor are influenced with regard to:

- Direction
- Velocity/rotational speed
- Force/Torque
- Position

Owing to the particular mode of operation of continuous adjustability of proportional valves and the variability of the control signals of the control electronics, hydraulic drives can be assigned the following characteristics by means of a proportional final control element:

- Velocity/rotational speed stages
- Force/Torque stages
- Specific deceleration
- Smooth changeover in general

Signal control

The signal control section with the signal generators produces the desired sequence.

In the main, the type of control required in practice is process controlled sequence control. A combination of time controlled operation and a logic control system is often required. In practice, this is predominantly realised by means of PLC controllers.

Programming model for writing of PLC programs

In this workbook, a programming model is available in the form of sequence tables, whereby the appropriate program can be easily written and converted with the individually available programming software. In addition, a solution in relay technology has been prepared and tested.

Signal generator

Nowadays, hydraulic systems are optimised using a multitude of signal generators.

The following are used in the training package TP702:

- Binary signal function
  - Limit switch
  - Inductive sensor
  - Capacitive sensor
  - Optical sensor

- Analogue signal function
  - Displacement sensor, potentiometric
  - Pressure sensor, piezoresistive
  - Temperature sensor, Resistance thermometer
  - Plus comparator card

Modes of operation and parameter conditions

In order to limit the extent of the exercises and to establish the essence of proportional hydraulics, just a simple setting-up operation has been integrated in some of the solutions.

Safety/Safety regulations

These are contained in the book purely with regard to the training operation. For reasons of space, safety regulations applicable in industrial practice have not been taken into account.

Systematic problem solving

Particular importance has been attached to a systematic procedure for problem solving: The structure of the solution has been designed so as to meet this by way of the problem definition. The solutions of most of the exercises have been structured as follows:

Understanding the exercise with the help of a positional sketch, diagram and problem description

The problem definitions and descriptions use various diagrams in line with industrial practice to illustrate the functional correlation of acceleration/deceleration in respect of time and distance. In proportional hydraulics, diagrams are the best form of describing sequences, whilst at same time representing a part of the solution of the problem.

Design of the hydraulic circuit diagram

The design of the components is based on the equipment set of TP702.

Alternative solutions are possible. The use of solenoid switching valve from equipment sets TP601 and TP602, further widens the possibilities for solutions.

Determining the required signal generator

The diagrams call for a particular sequence. Signal generators initiate the sequence of rapid traverse, acceleration, deceleration, etc. Once the necessary signal generators have been considered and determined, the signal control system can be prepared.

Preparing the sequence table

This facilitates the clear and systematic preparation of an example for the PLC programming or circuit design.

Individual control steps are to be specified and the input and output signals of the signal control system defined. In addition, the setpoint values and ramp addresses are to be specified.

Design of the electrical signal control system or writing of the PLC program

As stated above, you are absolutely free to write your own individual PLC program. For this workbook, TP702, relay controllers are to assume the signal processing function.

Electrical sequencers make good relay control systems. The defined signals of the sequence table can be assigned step-by-step when designing the system. The relay control systems are to be described in the solution description.

Construction and commissioning of the proportional hydraulic controller

In exercise 1, a procedure is recommended as an example.

Setting values in the solutions

The setting values you have established can and may vary from the values specifies. What is important is that the processes are practice-oriented and visually clearly arranged.

The basis for the setting values is the Festo Didactic standard hydraulic power pack with q pump = 2 l/min.

Alternative solutions

The exercises in this book are based on the equipment set TP702.

Alternative solutions are of course also possible for the exercises set.

Harmonization

In order to reach optimum functioning of a proportional valve, valves, control electronics, actuators and the hydraulic supply must be harmonized, whereby the following points are to be observed.

1. Problem definition

The problem definition provides a various basic data, which is important with regard to both layout and harmonization. This includes the working pressure, volumetric flow rate and the load of the consuming device as well as the output flow of the hydraulic power pack.

2. Modulation

The proportional amplifier must be adapted to the valve. To do this, the two limits according to which the adjustment is to be made must be known. The first limit is formed by the nominal current of the proportional solenoid, the other by the required or possible hydraulic value (pressure, flow rate).

This adaptation can be achieved by means of setting the I MAX values, whereby maximum current to be achieved with the maximum setpoint value is determined. This prevents damage to the proportional solenoids and at the same time simplifies the setpoint actuation, since a maximum of only 10 V can be used as a setpoint value. Not even an inadvertent overload is therefore no longer possible as far as the setpoint value is concerned.

Since the maximum current can be set separately for each output, it is for instance equally possible to balance different advancing and retracting speeds by means of different levels of I MAX values. Identical setpoint values for advancing and retracting also mean identical speeds.

3. Overlap

The overlap is the distance the valve piston needs to cover before the control edges open. With this design, leakage can be kept to a minimum even in the case of larger gaps around the valve piston. However, this design has a disadvance with regard to actuation. Since the valve piston re-adjusts in proportion to the magnetic flux, a certain amount of magnetic flux is necessary to overtravel this overlap. In the case of a proportional displacement valve, this means that flow will not start until a certain setpoint value has been reached.

However, what is desirable is an ongoing adjustment of the flow from a setpoint value of 0 to 10 V. This can virtually be achieved by means of a the jump current I JUMP, whereby the required magnetic flux is established and set for each direction. Right from the lowest setpoint value, an amount is added depending on the direction of the magnetic flux created by this setpoint value.

4. Basic current

If the drift of a cylinder or motor is to be compensated, this can be achieved with a directional control valve by means of shifting the mid position. By doing this, a greater leakage current is created on the side of the smaller overlap, which acts against the drift. Another application is in the sphere of the pressure control valve, where a specific pressure level is to be maintained at a setpoint value of 0 V.

This shift is performed via the basic current I BASIC.

Amplifier characteristics for a proportional directional control valve

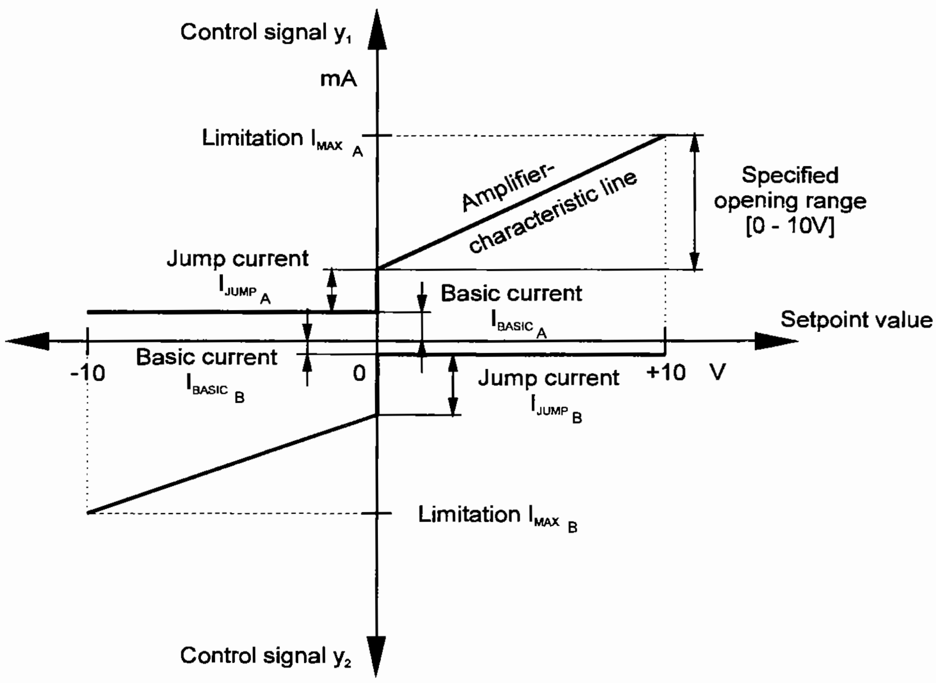


Fig. 5:
Amplifier characteristic for a proportional directional control valve

Adaptation of the proportioal pressure relief valve to thedesignated pressure setting range

1. Upper limiting value

As a rule, the designated highest pressure limiting value is set with I MAX at a setpoint value of 10 V. This is also a safety factor in that it is not possible to accidentally set a higher limiting value than that designated.

2. Lower limiting value

The lower limiting value of a system is generally connected to the circulation pressure of the pump without electrical connection. If the circulation pressue is for instance 7 bar, the basic current I BASIC at 0 volts is set to this value.

An optimum setpoint value resolution is given for the specified pressure setting range.

The electrical basic current once set remains permanently.

Amplifier characteristics for a proportional pressure relief valve

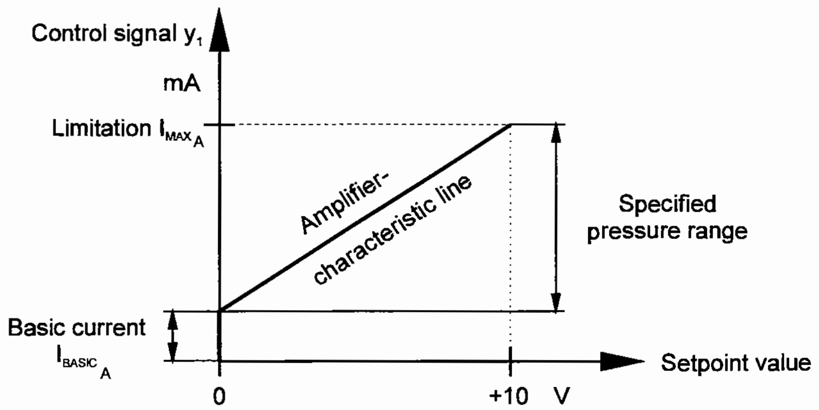


Fig. 6:
Amplifier characteristic for a proportional pressure-relief valve

Training contents of Proportional Hydraulics Advanced Level TP702

- Establishing the characteristic curves and parameters of various sensors.
- Harmonisation of electrical and hydraulic devices.
- Measuring of variables such as pressure, temperature, displacement and time.
- Control of pressure, speed, acceleration, deceleration and position.
- Reading and drawing up of proportional hydraulic and electrical circuit diagrams.
- Reading of motion diagrams.
- Application of symbols as specified in DIN/ISO 1219.
- Construction and commissioning of proportional hydraulic control systems including fault finding.
- Adaptation and harmonization according to the specified sequence description.
- Use of basic circuits of proportional hydraulics such as for:
  Velocity/rotational speed levels, acceleration/deceleration, differential circuits, positioning.

List of training aims of the exercises

Exercises	*Training aims*
1	To be able to plot the characteristic curve of a pressure sensor. To be able to realise the processing of the analogue signal from the temperature sensor.
2	To be able to plot the characteristic curve of a temperature sensor. To be able to realise the further processing of the analogue signal from the displacement sensor.
3	To be able to plot the characteristic curve of a displacement sensor. To be able to realise the further signal processing of the analogue signal from the displacement sensor.
4	To be able to draw up a specified displacement-time diagram for a press cylinder.
5	To be able to realise a specified positioning program. To be able to set an accurate switch-off position.
6	To be able to realise the drive acceleration by means of a proportional pressure relief valve.
7	To be able to realise the oscillating motion of a honing machine by means of a proportional hydraulic control system.
8	To be able to realise a specified speed pattern by means of an additional bypass circuit and softstop.
9	To be able to realise a injection moulding process using a worm motor and tapered cylinder by means of a 2/2-way proportional valve and a proportional pressure relief valve.
10	To be able to link two individual processes into one overall process. To be able to effect an optimum interconnection of a proportional flow control valve.

Equipment set – Proportional hydraulics Basic level TP701

Equipment set TP701
Order No. 184 465

Description	*Order No.*	*Quantity*
Relay plate, 3 off	162241	1
Signal input, electrical	162242	1
Proportional pressure relief valve	167087	1
Setpoint value card	162256	1
Proportional amplifier	162255	1
Pressure gauge	152841	2
Flow control valve	152842	1
One-way flow control valve	152843	1
Branch tee	152847	2
Pressure relief valve	152848	1
4/2-way solenoid valve	167082	1
Cylinder	152857	1
Hydraulic motor	152858	1
Proximity sensor, inductive	178574	2
Pressure filter	152969	1
Weight	152972	1
Pressure balance	159351	1
4/3-way proportional valve	167086	1

Equipment set – Proportional hydraulics Adavanced level TP702

Equipment set TP702
Order No. 184 466

Description	*Order No.*	*Quantity*
Relay plate, 3 off *)	162241	3
Time relay *)	162243	1
Indicator plate, electrical	162244	1
Cylinder mounting kit	120778	1
Comparator card	162257	1
Setpoint value card	162256	1
Non-return valve, 1 bar	152845	1
Branch tee	152847	1
Non-return valve, piloted	152852	1
Proximity sensor, capacitive **)	178575	1
Proximity sensor, optical*)	178577	1
Limit switch, electrical, left*)	183322	1
Limit switch, electrical, right *)	183345	1
Linear potentiometer	167090	1

Additional components for exercises 1 and 2

Description	*Order No.*	*Quantity*
Universal display	183737	1
Temperature sensor	184132	1
Pressure sensor	184133	1

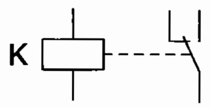
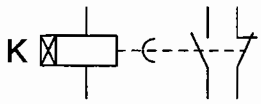
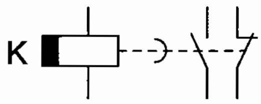
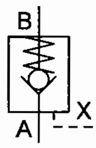
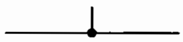
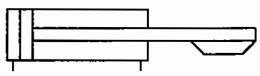
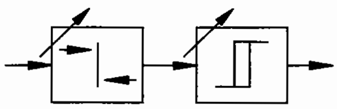
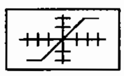
Additional components for exercise 10

Description	*Order No.*	*Quantity*
Pressure gauge	152841	2
Branch tee	152847	1
Hose 600 mm	152960	5
Relay plate, 3 off *)	162241	3
Time relay *)	162243	1
Proportional amplifier	162255	1
Setpoint value card	162256	1
4/2-way solenoid valve	167082	1
4/3-way proportional valve	167086	1
Proximity sensor, inductive	178574	1
Proximity sensor, capacitive	178575	1

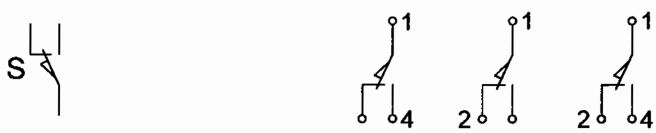
Accessories

Description	*Order No.*	*Quantity*
Digital multimeter	035681	1
Hose 600 mm	152960	7
Hydraulic power pack	152962	1
Pressure relieving device	152971	1
Hose 1500 mm	159386	4
Power supply unit	159396	1
Set of cables	167091	1

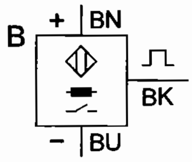
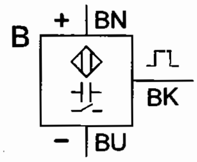
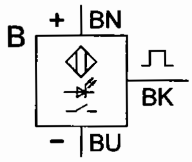
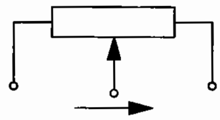
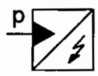
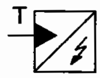
Symbols of equipment set TP702

Relay plate, 3 off 	Indicating device 
Time relay, pick-up delayed 	Zeitrelais, drop delayed 
Non-return valve 	Non-return valve, piloted 
Branch tee 	Cylinder mounting kit 
Comparator card 	Setpoint value card 

Limit switch, electrical, left and right



Symbols of equipment set TP702

Proximity sensor, inductive  	Proximity sensor, capacitive 
Proximity sensor, optical  	Linear potentiometer 
Pressure sensor  	Temperature sensor 

Allocation of components and exercises

Components	Exercises 1	2	3	4	5	6	7	8	9	10*
Relay plate, 3 off		2	1	4	4	2	4	3	4	7
Signal input, electrical			1	2	1	1	1	1	1	2
Time relay				1		1	1	1	1	2
Indicator plate		1					1			
Cylinder mounting kit			1				1			
Comparator	1	1	1				1			
Proportional pressure relief valve						1			1	1
Setpoint value card			1	1	1	1	1	1	2	3
Proportional amplifier			1	1	1	1	1	1	1	2
Pressure gauge	1	1		2	2	2	2	2	2	4
One-way flow control valve		1				1				
Non-return valve						1	1		1	1
Branch tee					1	3	3	1	2	4
Pressure relief valve						1	1			
Non-return valve, piloted					1					
4/2-way solenoid valve					1	1		1	1	2
Cylinder	1		1	1	1	1	1	1	1	2
Hydraulic motor									1	1
Proximity sensor, inductive				1	1	1		1	1	2
Proximity sensor, capacitive				1	1	1		1	1	2
Proximity sensor, optical				1	1					
Limit switch, electrical, left				1	1	1		1		1
Limit switch, electrical, right				1	1			1		1
Pressure filter			1	1	1	1	1	1	1	1
4/3-way proportional valve			1	1	1		1	1	1	2
Set of cables	1	1	1	1	1	1	1	1	1	2
Power supply unit	1	1	1	1	1	1	1	1	1	1
Hydraulic power pack	1	1	1	1	1	1	1	1	1	1
Hose 600		1	3	3	7	6	5	5	6	12
Hose 1500	1		2	2	2	3	2	2	4	4
Universal display		1								
Pressure sensor	1									
Temperature sensor		1								
Displacement sensor			1							

* Exercise 10 requires a number of components, which are additional to those contained in equipment set TP700. In exercise 10, the circuits resulting from exercises 8 and 9 are linked to form a more complex overall function.

Methodical structure of the exercises

The workbook is structured in the form of exercises in section A and solutions to exercises in section C. The methodical structure is identical for all exercises.

- The exercises in **section A** are divided into:
  - Subject
  - Title
  - Training aim
  - Problem definition
  - Problem description
  - Positional sketch

- This is followed by the worksheet for the practical implementation of the exercise using:
  - Block diagrams
  - Symbols for circuit diagrams
  - Setting aids
  - Evaluation aids such as
Value tables for measured values,
Coordinates for characteristic curves
  - Revision

- The solutions in **section C** contain:
  - Hydraulic circuit diagram
  - Electrical circuit diagram
  - Component list
  - Setting table
  - Solution description
  - Evaluation
  - Conclusion

Section A – Course

Subject

Proportional hydraulics

Titie

Pressure sensor

Training aim

- Familiarisation with the mode of operation and signal processing of analogue sensors.
- To specifically learn about the mode of operation and characteristic curve of a **pressure sensor**.
- To be able to understand and carry out the signal processing of **analogue signals** by means of a **comparator card**.

Problem definition

- Constructing the measuring circuit.
- Plotting the characteristic curve of a pressure sensor.
- Setting the threshold values.

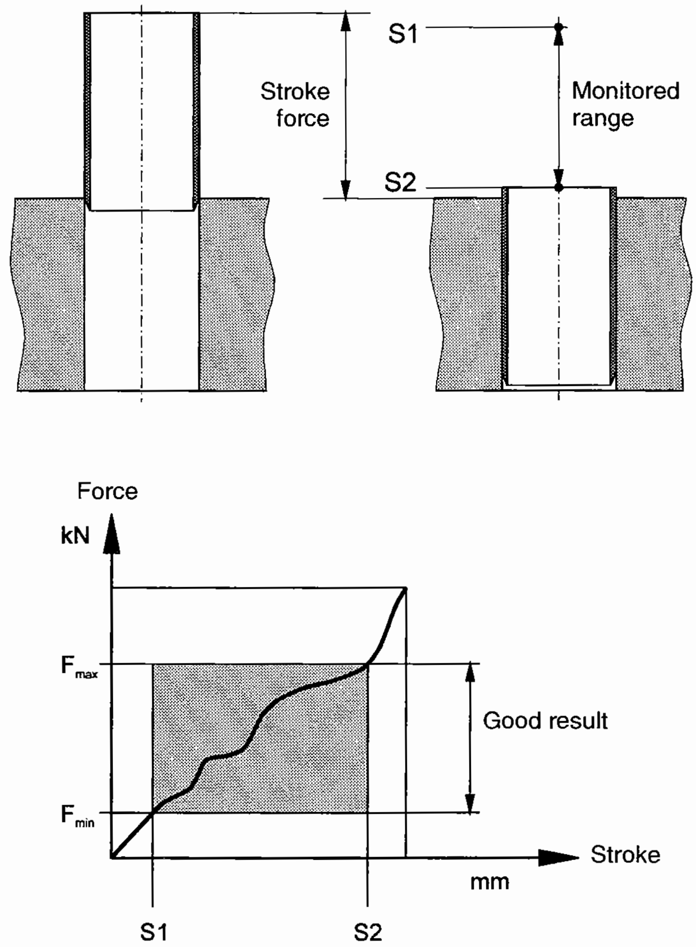
Problem description

For the purpose of integral quality assurance, state-of-the-art presses have been equipped with control systems to monitor the pressing force.

In this way, the joining and pressing process is monitored for "Good" or "Reject" parts. An analogue pressure sensor has been installed as a signal generator for the pressure characteristics.

During the commissioning of the press, the characteristic curve of the pressure sensor is to be checked and the threshold values 20 and 40 bar set subsequently as limit values for the monitoring

Fig. 1/1: Positional sketch



WORKSHEET

Plotting the characteristic curve for the overall pressure input range

- The analogue measuring encoder converts the measured physical variable pressure into an analog electrical signal.
- The input variable of the pressure sensor is the hydraulic pressure P in the range of 0 to 100 bar.
- The output signal of the pressure sensor is the normal electrical standard voltage of 0 - 10 Volts.

Plotting of characteristic curves

- Familiarise yourself with the components. See also the operating instructions and data sheets.
- Construct the complete measuring circuit. The hydraulic cylinder is connected up in the form of a pressure intensifier, which means that the retracted end position and rod chamber are filled with oil.
- Check the origin of the characteristic curve:
  Input signal = 0 bar, readable on the pressure gauge.
  Output signa l= 0 Volt, readable on the comparator card.
- Switch on the hydraulic power pack.
  Use the pressure relief valve to accurately set the intensified pressures in accordance with the table.
  Note the rising and falling measuring direction. Take a reading of the allocated electrical voltage values.
  Note that the pressure gauge must not be loaded in excess of 3/4 of the maximum scale reading (75bar/7.5 MPa).
- Enter the values in the table and draw the appropriate points in the coordinate system.
  Connect the points to form a characteristic line.
- Evaluate the plotted characteristic curve and the characteristic curve determined.

Fig. 1/2:
Circuit diagram, hydraulic

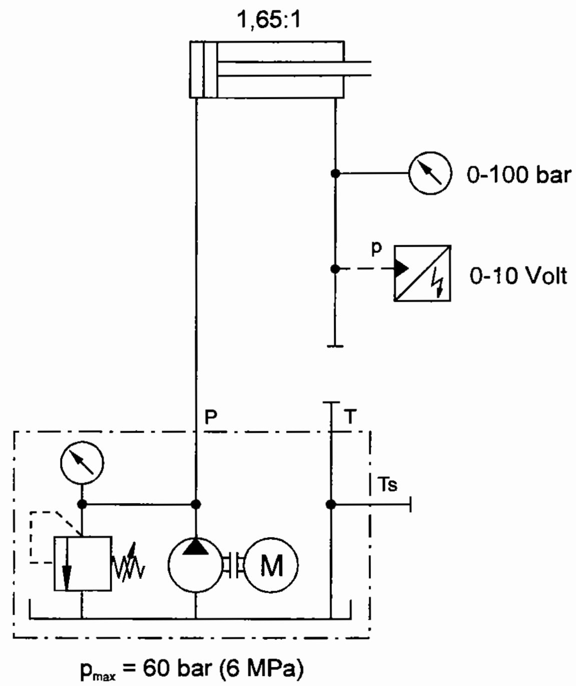
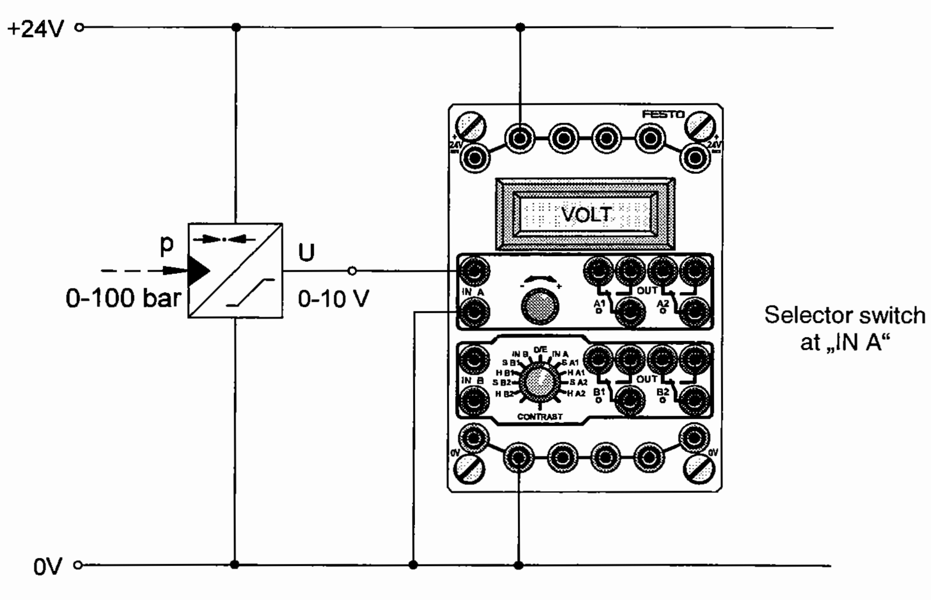


Fig. 1/3:
Circuit diagram, electrical



WORKSHEET

Value table

Measured variable and unit	Measured values								Measuring direction
Pressure p in bar	0	10	20	30	40	50	60	70	
Voltage V in volts									rising
Voltage V in volts									falling

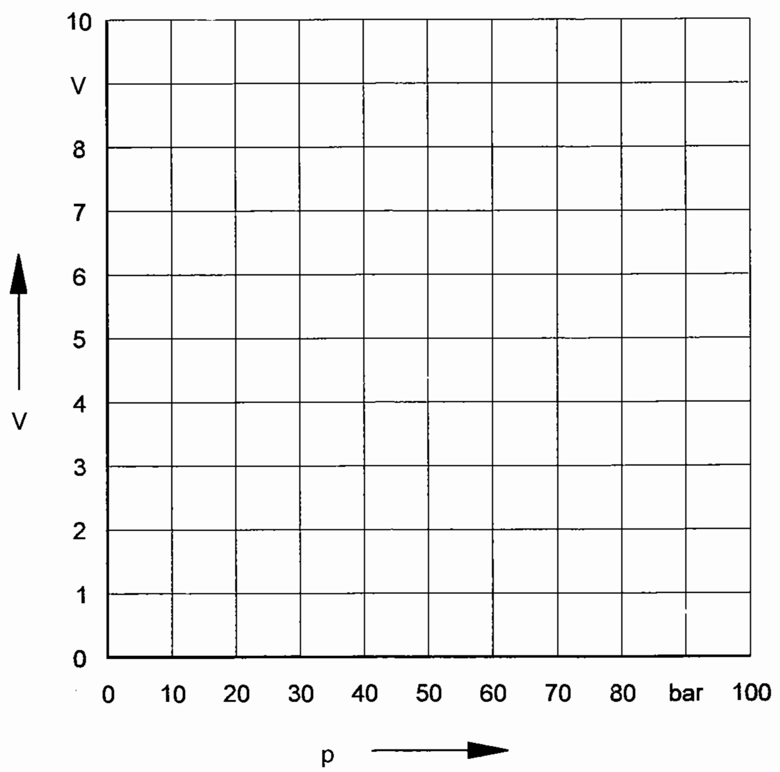


Fig. 1/4: Characteristic line Pressure/electrical voltage

Conclusion

Explain the terms binary signal, binary signal generator, analogue signal and analogue signal generator.

Subject

Proportional hydraulics

Title

Temperature sensor

Training aim

- Familiarisation with the mode of operation of a **temperature sensor**.
- To be able to understand and carry out the signal processing of **analogue signals** by means of a **comparator card**.

Problem definition

- Designing the measuring circuit.
- Checking the signal output of the temperature sensor.
- Designing the temperature monitoring control.
- Constructing and commissioning the temperature monitoring control.

Problem description

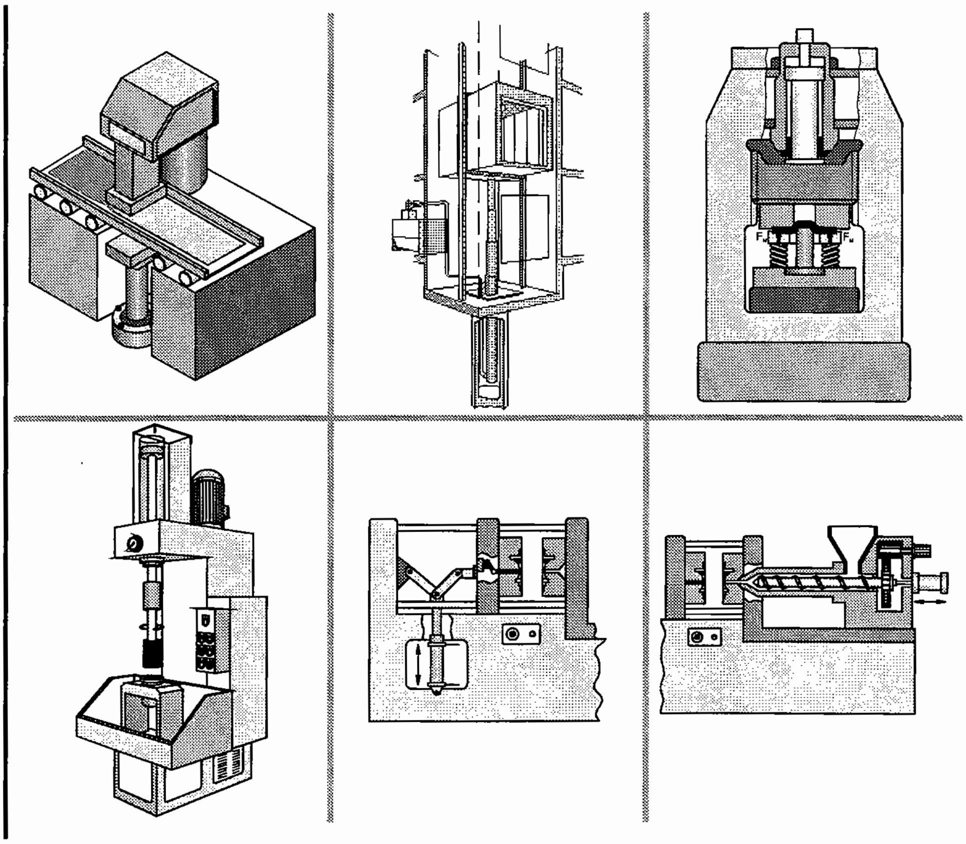
Temperature monitoring

An oil temperature monitoring control is to be designed for exercises 4 to 10 in this workbook. This control should be easily integratable into all of the solutions. A temperature sensor with a range of 0 to 100° C is to be used to establish the temperature. First, the electrical output voltage analogous to the temperature is to be checked.

The following conditions apply with regard to the monitoring control.

- The pump output temperature is to be established. The measured value acquisition is therefore effected on the P-connection of the hydraulic power pack.
- The ready status is designated to be from 25° C to 40° C. If the temperature exceeds or drops below this range, then the signal lamp is to be illuminated and a restart should not be possible.

Fig. 2/1:
Positional sketch



WORKSHEET

Checking the signal output within the possible oil temperature range

- The analogue measured value sensor converts the physical variable temperature to be measured into an analogue electrical signal.
- The input variable of the temperature sensor is the oil temperature T within a range of 0 - 100 °C.
- The output signal of the temperature sensor is the normal standard electrical voltage V from 0 – 10 V.

Test procedure

- Familiarise yourself with the components.
  See also operating instructions and data sheets.
- Construct the entire measuring circuit.
- Measure the currently existing electrical output voltage and take a reading of the temperature allocated.
  To do this, set the hand-held measuring device to temperature measurement and the comparator card to electrical voltage measurement.
- Switch on the hydraulic power pack.
  Set a pressure drop of 50 bar with the help of the flow control valve. A continually rising oil temperature is created as a result of the power dissipation via the flow control valve (frictional and acceleration dissipation). This dissipation mainly heats the oil and a small part is emitted via the components due to heat emission. With this relatively high power dissipation for our test, the temperature at the measuring point rises rapidly, since the temperature of the oil supply is continually increasing.
- Take a reading of the analogue electrical voltage values for the temperature measuring points specified.
  Enter the values in the table.

Fig. 2/2:
Circuit diagram, hydraulic

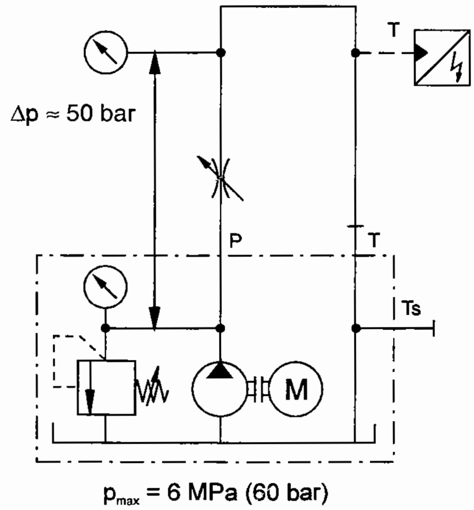
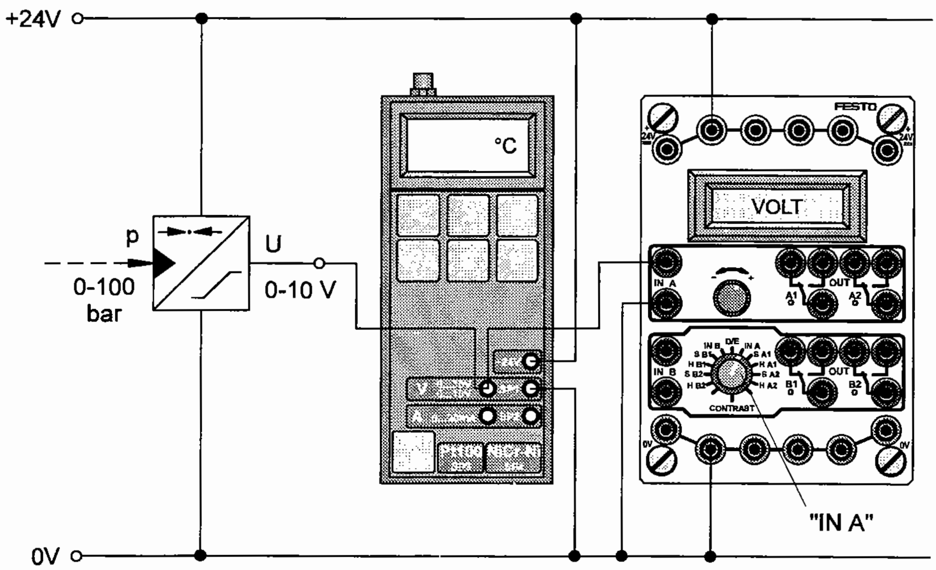


Fig. 2/3:
Electrical circuit diagram



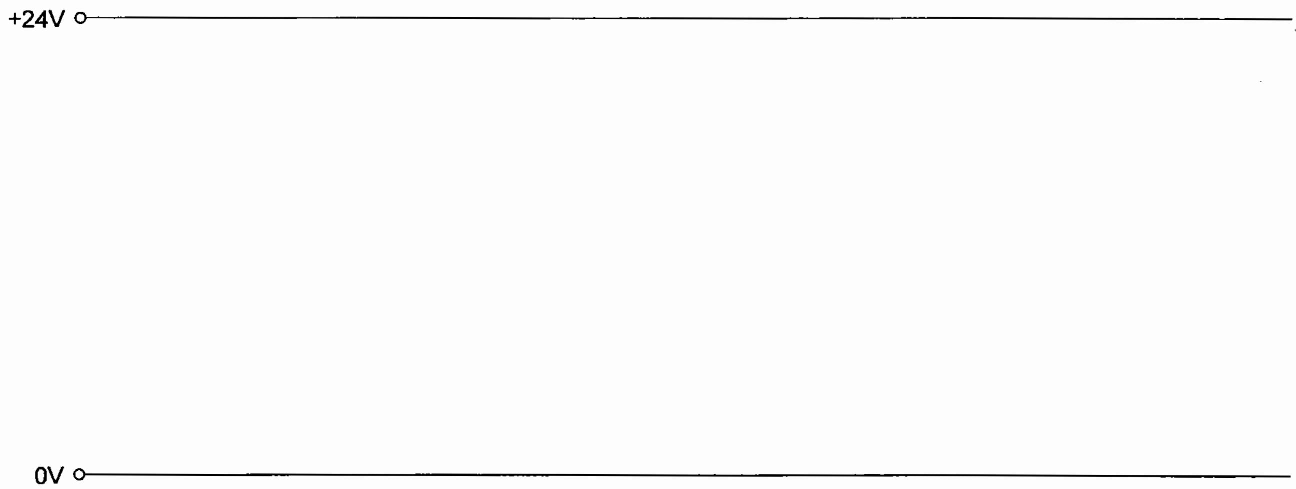
WORKSHEET

Measured variable and unit	*Measured values*			*Measuring direction*
Temperature T in °C	25	30	40	
Voltage V in volts				rising

Value table

Fig. 2/4: Logic diagram

Fig. 2/5: Circuit diagram, electrical



Conclusion

What are the advantages of using a temperature sensor and comparator card to monitor the temperature-ready status?

Subject

Proportional hydraulics

Title

Displacement sensor

Training aim

- Learning about the mode of operation and characteristic curve of a **displacement sensor**.
- To be able to understand and realise the further processing **analogue signals** by means of a **comparator card**.

Problem definition

- Constructing the measuring circuit, attaching and adjusting the displacement sensor.
- Checking the signal output of the displacement sensor.
  Plotting the characteristic curve of a displacement sensor.
- Designing the basic control.
- Limit sensing on hydraulic drives by means of a displacement sensor comparator card.
- Constructing and commissioning the basic circuit.

Problem description

Oscillating hydraulic drives, such as on honing machines and surface grinding machines, have infinitely adjustable reversal point. Advanced displacement sensors and comparator cards, provide an ideal solution for end position sensing and infinite repositioning.

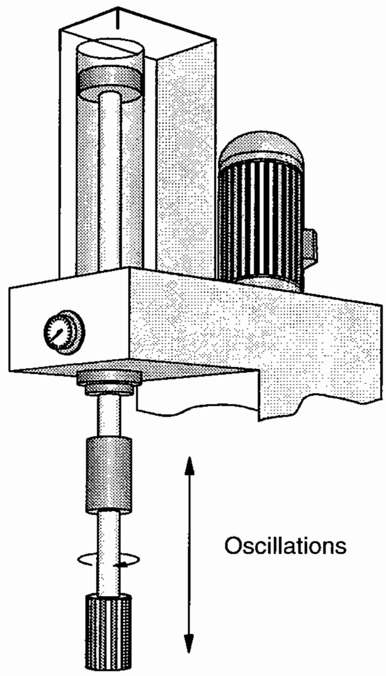
The signal output of the displacement sensor is to be checked within the cylinder stroke range for an existing installation and the basic circuit designed for the corresponding hydraulic drive.

The following conditions apply:

- A start must only be possible when the retracted end position has been reached.
- It must be possible to infinitely reposition the forward reversal point within a wide range.

The hyraulic circuit diagram, the displacement-step diagram and the sequence table are specified, so that only the signal control remains to be designed.

Fig. 3/1: Positional sketch



WORKSHEET

Checking the signal output of the displacement sensor within the cylinder stroke range

- The analogue measuring sensor converts the physical variable to be measured, i.e. length, into an analogue electrical signal.
- The input variable of the displacement sensor is the stroke length L of 0 – 200 mm.
- The output signal of the displacement sensor is the normal standard electrical voltage V from 0 to 10 Volts.

Test procedure

- Familiarise yourself with the components. See also operating instructions and data sheets.
- Construct the entire measuring circuit.
- Mount the displacement sensor.

  The following data in the data sheet applies:

Sensor:	Mechanical stroke:	201 mm
	Measuring stroke:	200 mm
Hydr. Cyl.:	Stroke:	200 mm

During the assembly stage, the measuring slide is to be connected to the cylinder rod so as to protect the measuring system, whereby the mechanical end positions of the displacement sensor are not reached.

Theoretically, this should ensure that the signal 0 V or 10 V is supplied in the cylinder end positions. This may vary subject to tolerances. The training concept of TP 702 is designed for binary signal processing only, whereby binary signal with a defined signal level of 0 V and 24 V are available for the logic signal operation by means of threshold value generators (comparator card).

This means, that the zero point of the cylinder (retracted end position) does not necessarily have to coincide with the zero point of the displacement sensor. For the retracted cylinder end position, for instance, 0.18 volts may be allocated. A threshold value generator would be set slightly higher than this. See also basic control.

- The 4/3-way proportional valve with its control electronics is to be used to position the hydraulic cylinder in accordance with the length specified in the value table.

  To do this, the internal setpoint value W1 of the control electronics is to be activated via 24 volt signals, whereby the cylinder can be finely adjusted using the setpoint generator. At the same time, set a jump current I JUMP of approx. 50 mA for both directions, and an I MAX current of approx. 800 mA.

- Any type of tape measure may be used for the length measurement.

- Read the allocated electrical voltage values in addition to the specified length values. With this, the values in the mechanical end positions of the hydraulic cylinder are important.

  Considerable measuring errors may occur. However, the accuracy of a measuring circuit and measured value acquisition of this type is generally adequate to check the sensor function.

- Note the values in the table and enter the corresponding points in the coordinate system.

WORKSHEET

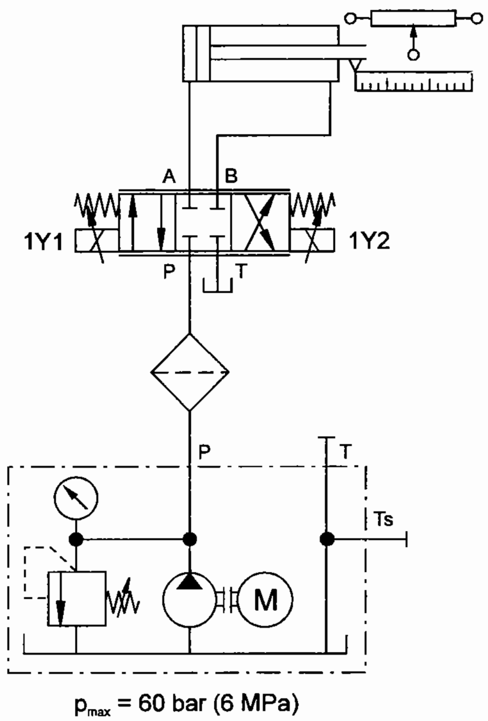


Fig. 3/2:
Circuit diagram, hydraulic

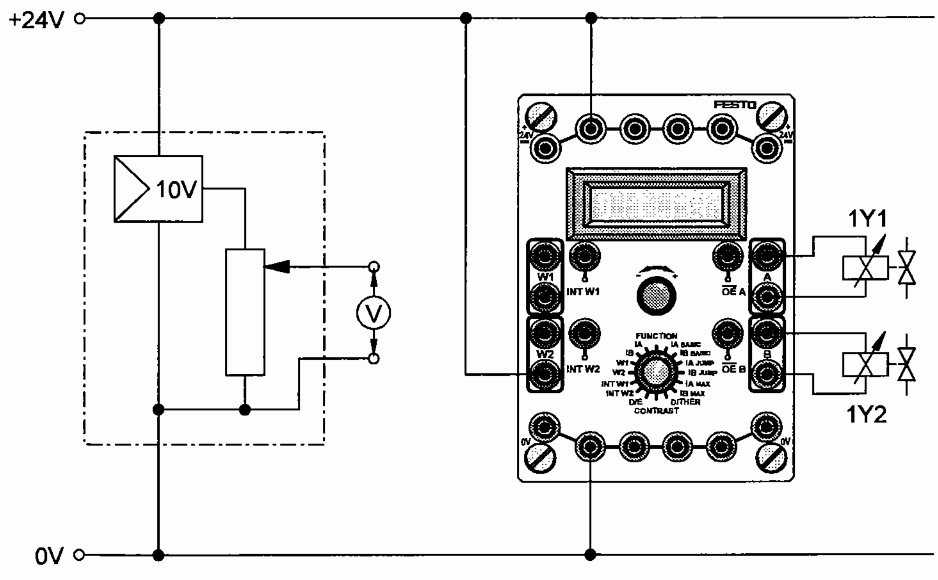
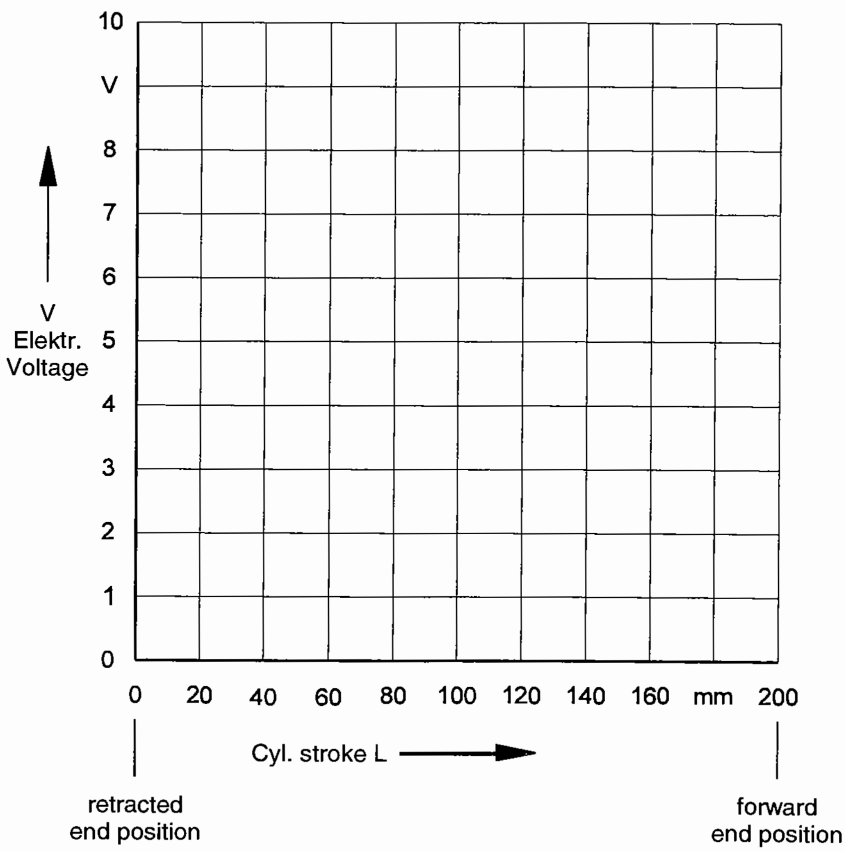


Fig. 3/3:
Circuit diagram, electrical

Value table

Measured variable and unit	*Measured values*					*Measuring direction*
Cylinder stroke in mm	0 retracted end position	50	100	150	200 forward end position	
Voltage V in volts						rising
Voltage V in volts						falling

Fig. 3/4: Diagram Stroke/voltage



WORKSHEET

Designing the basic control for limit sensing on hydraulic drives

Given are the hydraulic power section, the displacement-step diagram and the sequence table.

Design the electrical signal control for this.

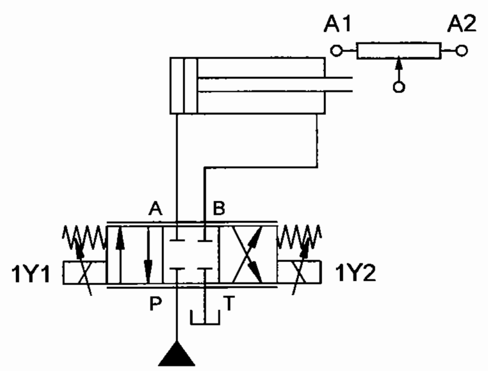


Fig. 3/5:
Circuit diagram, hydraulic

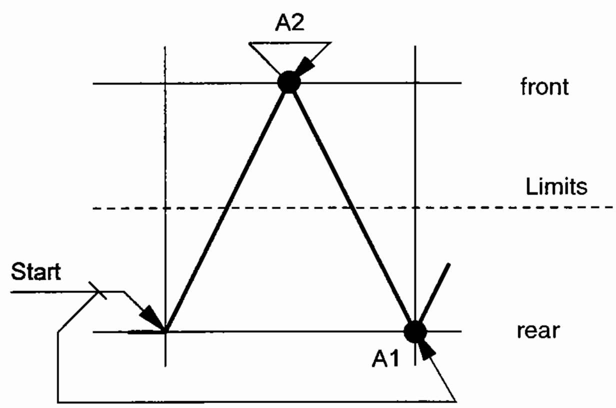


Fig. 3/6:
Displacement-step diagram

Sequence table

Step	*Sequence*	*Setpoint value* $1Y1 \rightarrow +$ $1Y2 \rightarrow -$	*Setpoint value polling* *I1*	*I2*	*I3*	*Ramp-setting*
1	Advance	W2 + 10 V	1	0	0	Zero
2	Retract	W1 - 10 V	0	0	0	Zero

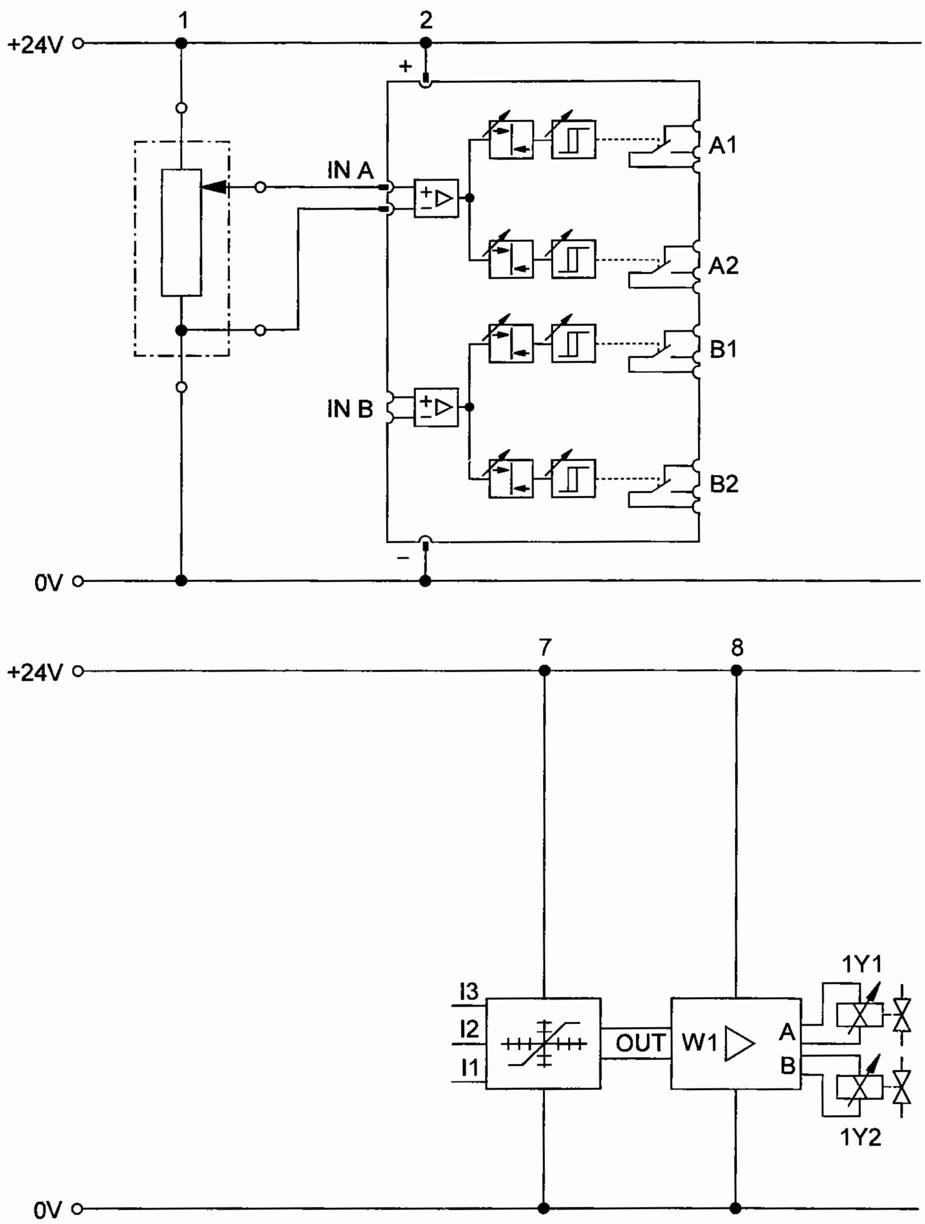


Fig. 3/7:
Circuit diagram, electrical

WORKSHEET

Conclusion

Why is it necessary to fall below the threshold value with systems using displacement sensors and a comparator card to detect the retracted end position?

Subject: *Proportional hydraulics*

Title: **Curing press**

Training aim

- To be able to realise a required **displacement-step diagram** for a pressing cylinder.

Problem definition

- Familiarising yourself using the positional sketch, displacement-time diagram and problem definition.
- Designing the hydraulic circuit diagram.
- Defining the required signal generators in the displacement-time diagram.
- Drawing up the sequence table.
- Designing the electrical signal control.
- Constructing the complete proportional hydraulic control system.
- Commissioning:
  - Harmonizing of the proportional directional control valve and the proportional amplifier.
  - Adjusting the signal generator.
  - Setting the required cylinder speeds by means of setpoint values.
  - Setting the acceleration and deceleration by means of ramps.
  - Fine-tuning of all the above points.

Problem description

A curing press is used to cure a strip of wet imitation leather. The press stamp is actuated by means of a double-acting hydraulic cylinder.

An optical sensor starts the squeezing cycle when the strip of leather has been fed by an indexing conveyor belt.

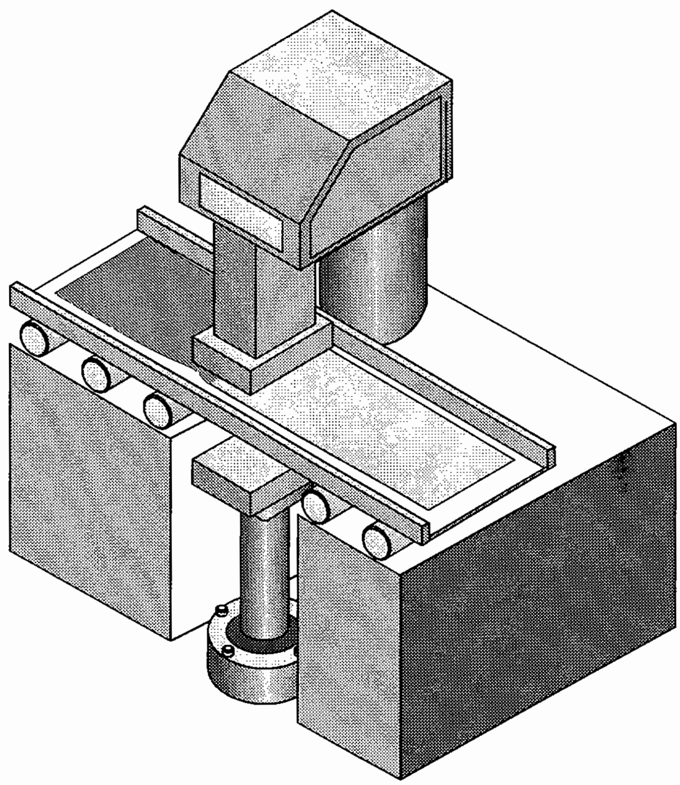
The press stamp is accelerated to a high rapid traversing speed and is then gently pushed down on the imitation leather. The squeezing position is kept under maximum pressure for an adjustable period of time.

This is followed by a partial return stroke and a smooth reversal of direction to maximum stroke speed. The cylinder with its squeezing press now approaches the imitation leather on the conveyor without braking. This is to ensure optimum squeezing as a result of this additional pressing impact, prior to proceeding to the drying system.

The return stroke is effected by means of acceleration and gentle retracting into the initial position. The return stroke speed is reduced by approx. 20 %, due to the weight of the press.

A signal is triggered in the lower end position in order to advance the conveyor belt. The squeezing cycle is started again by the optical sensor.

Fig. 4/1: Positional sketch



WORKSHEET

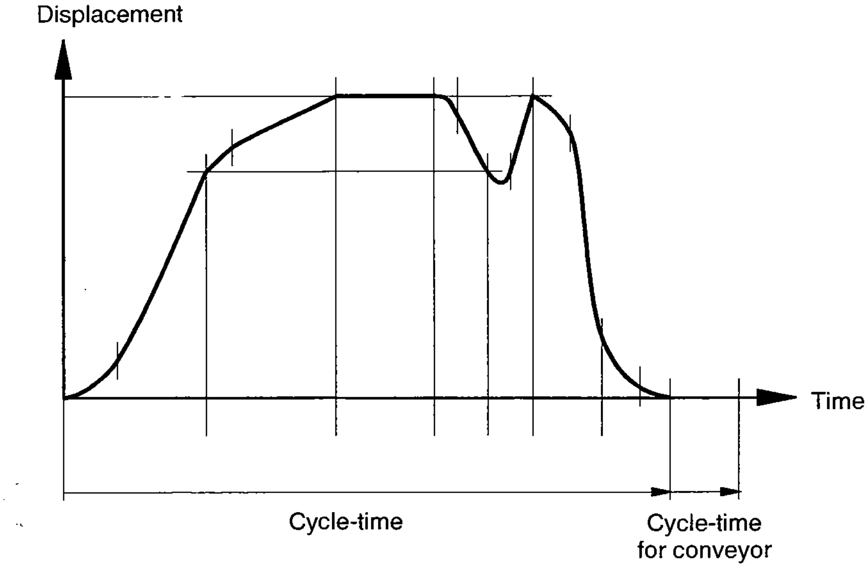


Fig. 4/2:
Signal generator in the displacement-time diagram

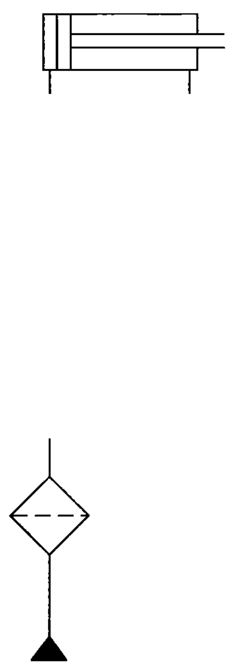


Fig. 4/3:
Circuit diagram, hydraulic

Sequence table

Step	*Sequence*	*Signal generator*	*Setpoint value* $+ \to 1Y1$ $- \to 1Y2$	*Setpoint value polling* I1	I2	I3	*Ramp*	*Comment*
Setting-operation	Advancing/ retracting with optional stops							
Auto-matic	Initial position							
1	Acceleration to stroke speed							
2	Decelerating to creep speed							
3	Pressing for cur-ing							
4	Acceleration for partial return stroke							
5	Smooth reversing action for forward stroke							
6	Acceleration to return stroke speed							
7	Deceleration to creep speed							
8	Initial position							

WORKSHEET

Fig. 4/4:
Signal control, electrical

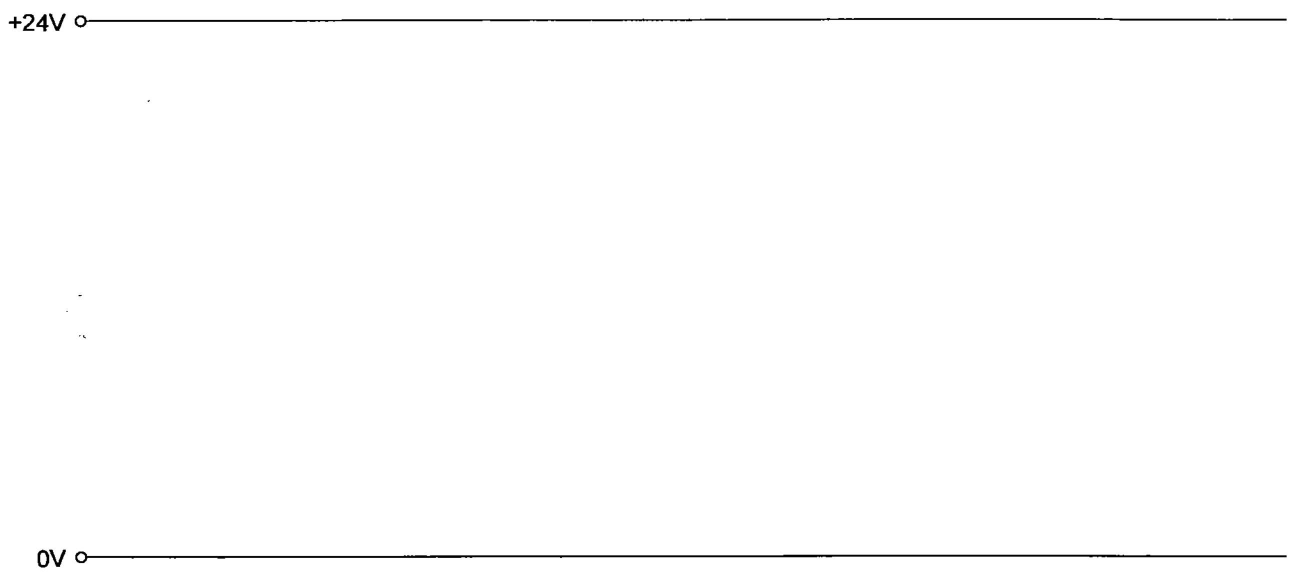
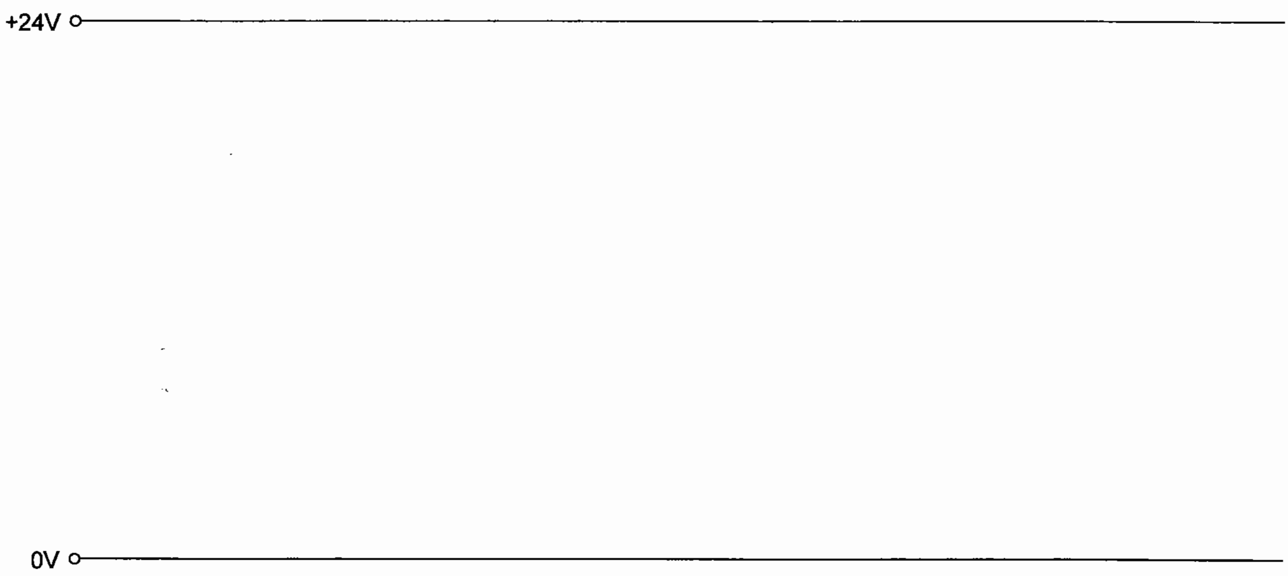
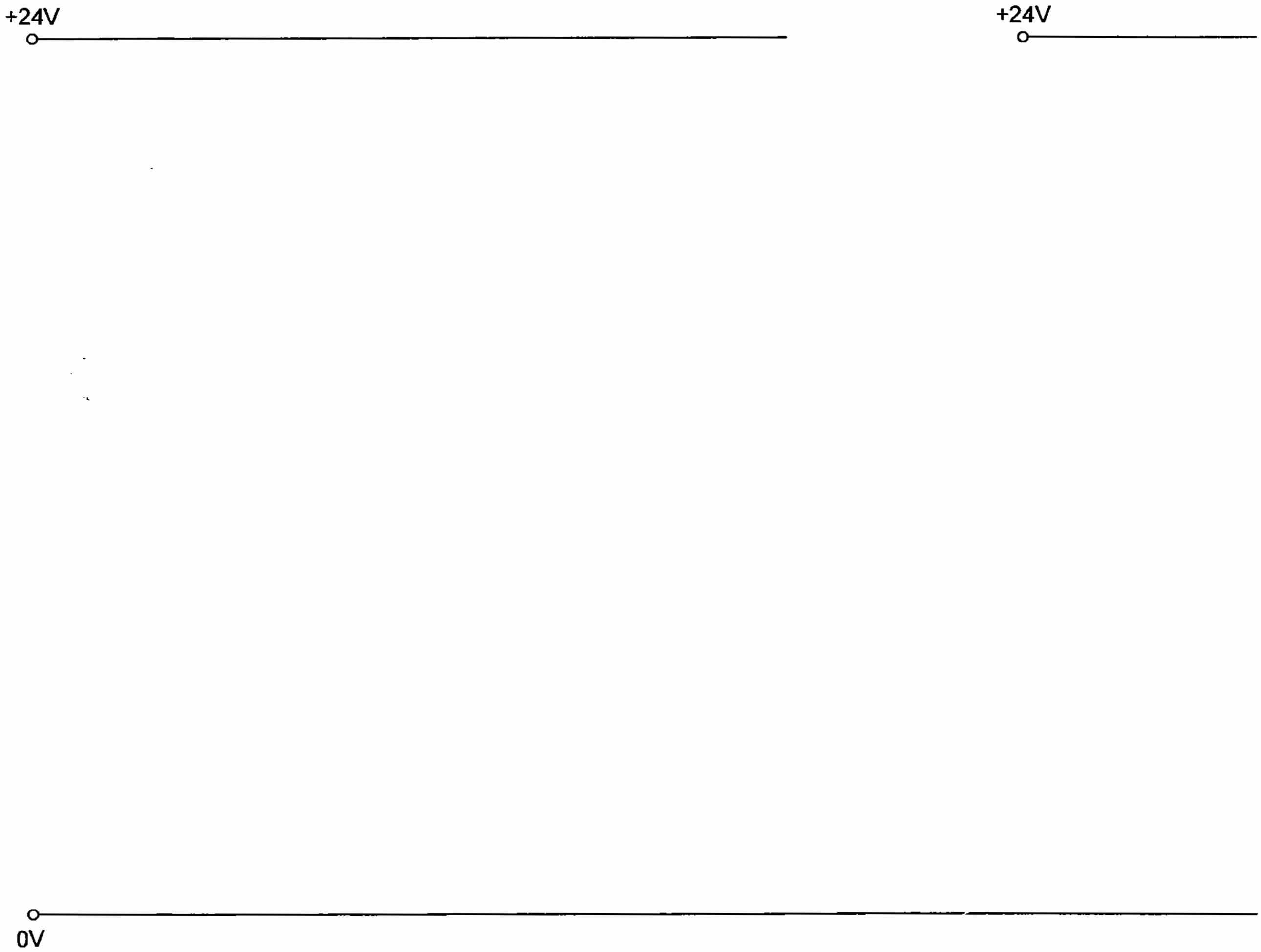


Fig. 4/5:
Signal control, electrical



WORKSHEET

Fig. 4/6:
Signal control, electrical



Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	
IA BASIC	
IA JUMP	
IA MAX	
IB BASIC	
IB JUMP	
IB MAX	
DITHERFREQ	

Conclusion

What are the setting measures used during commissioning to achieve the optimum setting of the motion sequence?

Subject

Proportional hydraulics

Title

Hydraulic lift

Training aim

- To be able to realise a required **positioning diagram** with accurate **switch-off positioning**.

Problem definition

- Familiarising yourself with the exercise using the speed-displacement diagram and problem description.
- Designing the hydraulic circuit diagram.
- Defining the required signal generators in the speed-displacement diagram.
- Drawing up the sequence table.
- Designing the electrical signal control.
- Constructing the complete proportional hydraulic control system.
- Commissioning:
  - Harmonizing the proportional directional control valve and proportional amplifier.
  - Adjusting the signal generator.
  - Setting the required speeds by means of setpoint values.
  - Setting the acceleration and deceleration by means of ramps.
  - Fine-tuning all of the above points.

Problem description

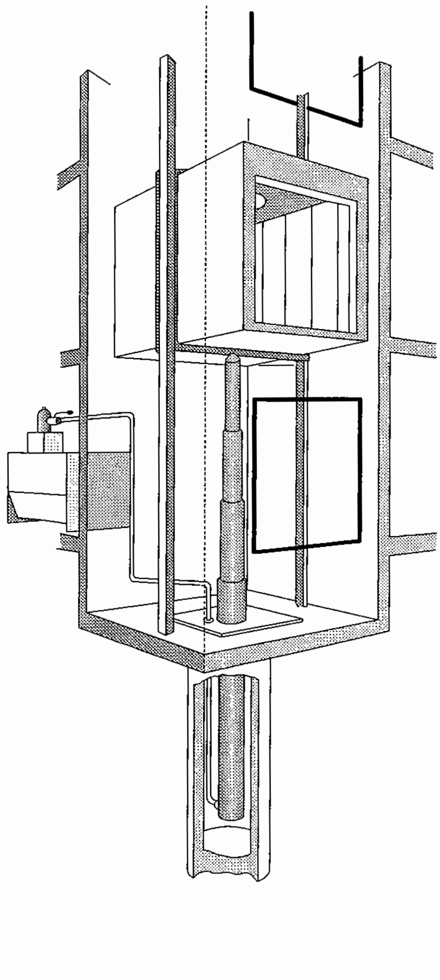
A block of flats with four floors has been designed with a hydraulic lift. The lift cabin is actuated by means of a hydraulic telescopic cylinder. Upward and downward travel to the respective floor positions must take place in accordance with the specified positioning diagram.

Positioning during upward travel of the lift is effected by means of deceleration on creep speed and stopping once the position has been reached. When travelling downward, the designated higher lowering speed must be smoothly decelerated in two stages.

In order to limit the extent of the exercise, the signal control is designed merely for upward and downward travel into the respective positions. Any other signal logic for several floors, generally used for a lift, are omitted. Similarly, none of the safety regulations and requirement applying to the hydraulic and electrical control have been taken into account.

For this exercise, the telescopic cylinder is replaced by a double-acting cylinder.

Fig. 5/1: Positional sketch



WORKSHEET

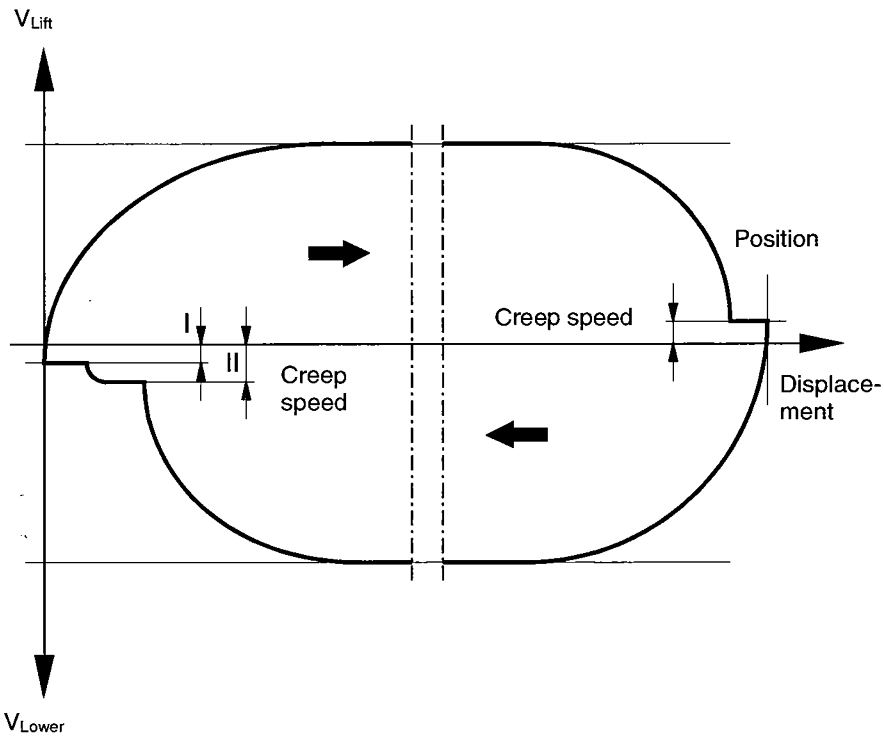


Fig. 5/2:
Signal generator with positioning diagram

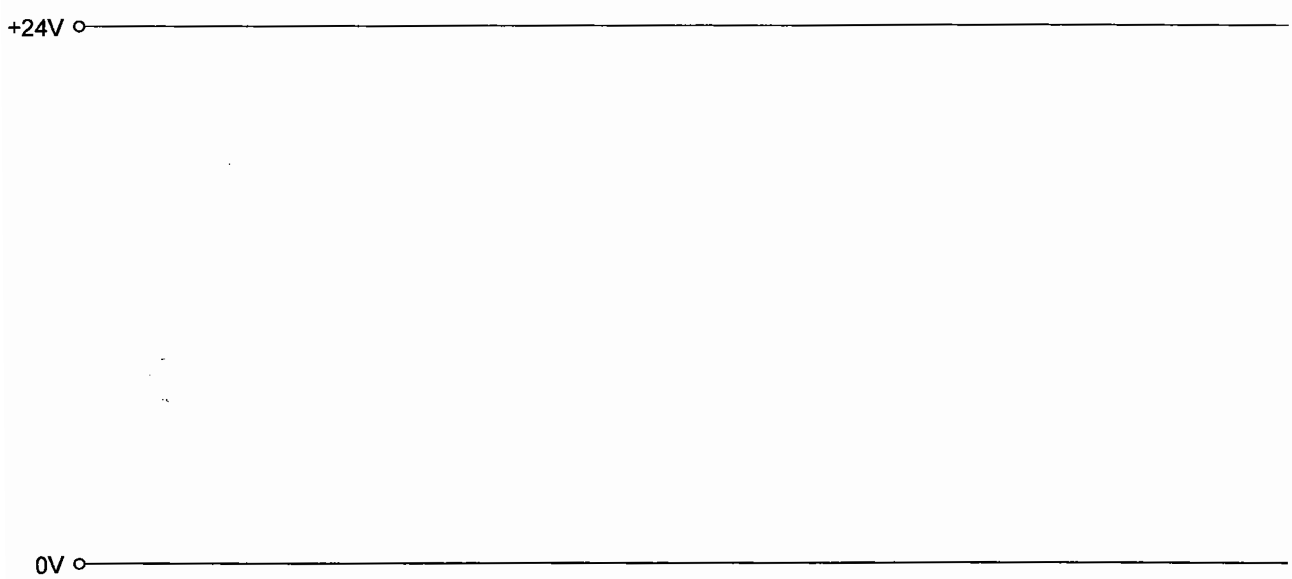
Fig. 5/3:
Circuit diagram, hydraulic

WORKSHEET

Sequence table

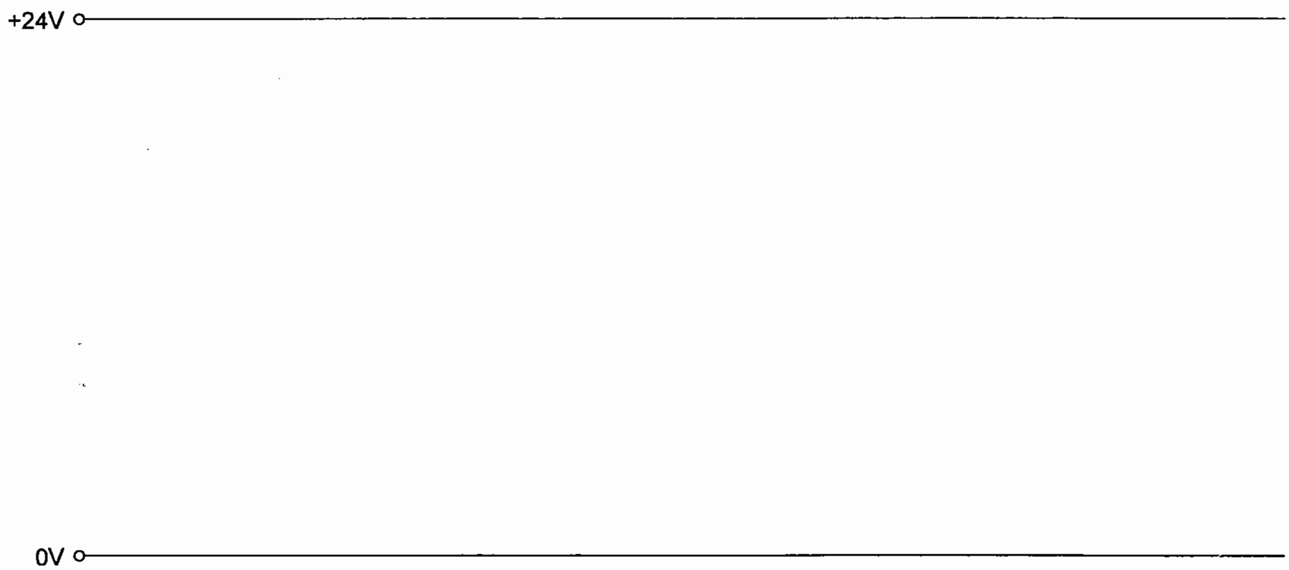
Step	*Sequence*	*Signal generator*	*Setpoint value* $+ \rightarrow 1Y1$ $- \rightarrow 1Y2$	*Setpoint value polling* I1	I2	I3	*Ramp*	*Amplifier output* $\overline{OA}$ A	$\overline{OA}$ B	*1Y3*	*Comment*
Setting operation	Advancing/ retracting with optional stops										
1	Acceleration to stroke speed										
2	Deceleration to creep speed										
3	Positioning										
1	Acceleration to lowering speed										
2	Deceleration to creep speed II										
3	Deceleration to creep speed I										
4	Positioning										

Fig. 5/4:
Signal control, electrical



WORKSHEET

Fig. 5/5:
Signal control, electrical



Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	
IA BASIC	
IA JUMP	
IA MAX	
IB BASIC	
IB JUMP	
IB MAX	
DITHERFREQ	

Conclusion

Does the switching time of the electrical signal control influence the position during stopping?

Subject

Proportional hydraulics

Title

Drawing press

Training aim

- To be able to realise the **drive acceleration** by means of a **proportional pressure relief valve**.

Problem definition

- Familiarising yourself with the exercise using the positional sketch, displacement/time diagram and problem description.
- Designing the hydraulic circuit diagram.
- Defining the required signal generators.
- Drawing up the sequence table.
- Designing the electrical signal control.
- Constructing the complete proportional hydraulic control system.
- Commissioning:
  - Harmonising the proportional pressure valve and proportionalamplifier.
  - Adjusting the signal generator.
  - Setting the required pressure values by means of setpoint values.
  - Setting the acceleration by means of ramps.
  - Fine-tuning all of the above points, including the harmonisation of the amplifier.

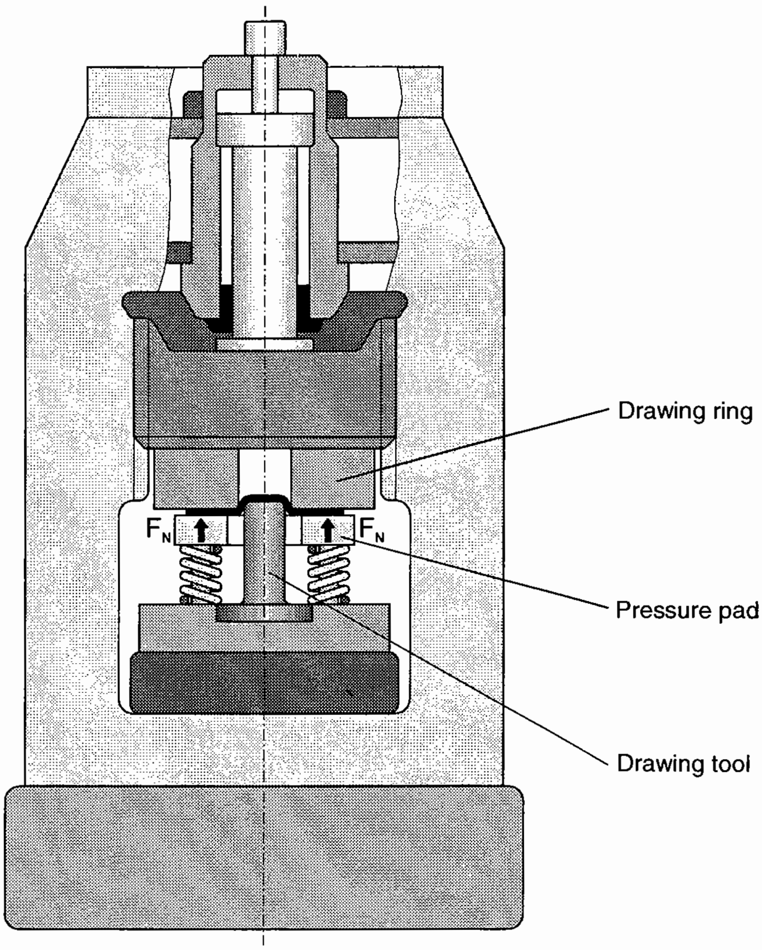
Problem description

Hydraulic drawing presses are machine tools used for non-cut forming operation. Hollow parts are deep drawn from sheet steel. The pressure pad decelerates the material flow into the drawing gap and eliminates tearing. The pressure pad force originates from the pressure springs.

The drawing tool is actuated by a hydraulic cylinder. The forming process must start smoothly with reduced force and then increase via ramps; the metal is thus able to flow and does not tear.

The load of the drive and the mechanical structure is to be kept as low as possible. This is to be achieved by means of a smooth reversal of direction after drawing and acceleration for the return stroke, as well as a low pressure stage for retracting into the initial position.

Fig. 6/1: Positional sketch



WORKSHEET

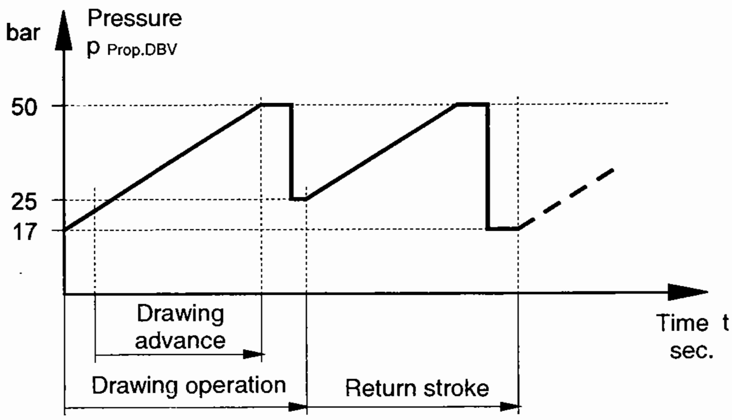


Fig. 6/2:
Signal generator in
Pressure-time diagram

Fig. 6/3:
Circuit diagram, hydraulic

Sequence table

Step	*Sequence*	*Signal generator*	*Setpoint value*	*Setpoint value polling*			*Ramp*	*1Y*	*Comment*
			+ → 0Y	*I1*	*I2*	*I3*			
1	Acceleration for advancing and drawing action								
2	Preparing return stroke – Start - Time function								
3	Acceleration for return stroke								
4	Low pressure stage for smooth retracting								
5	Initial position								

WORKSHEET

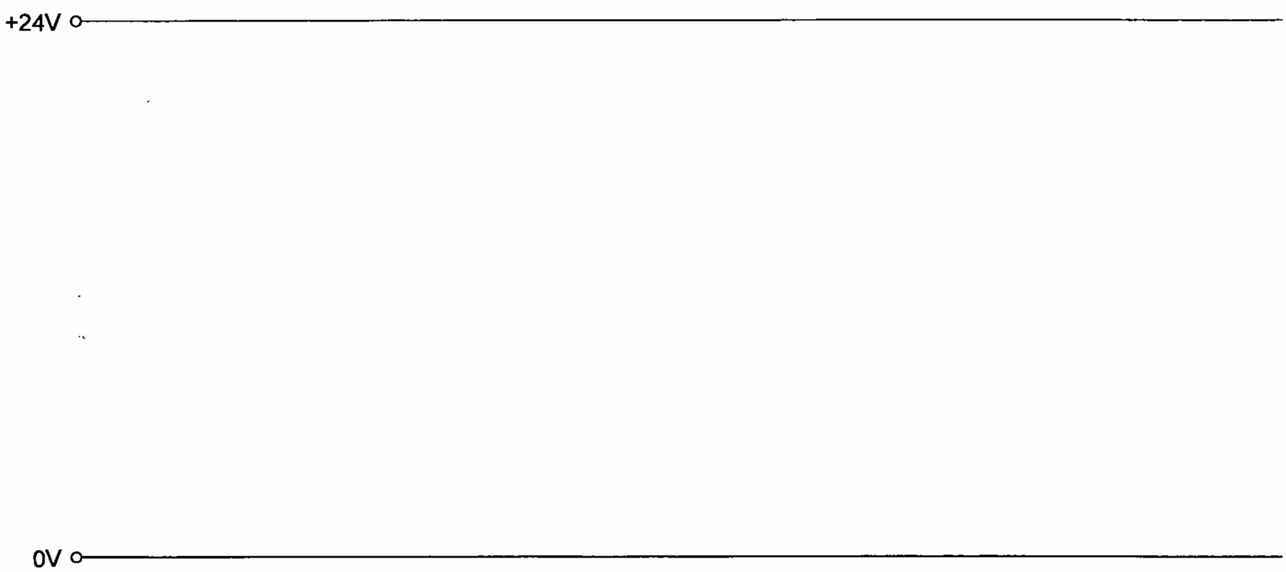
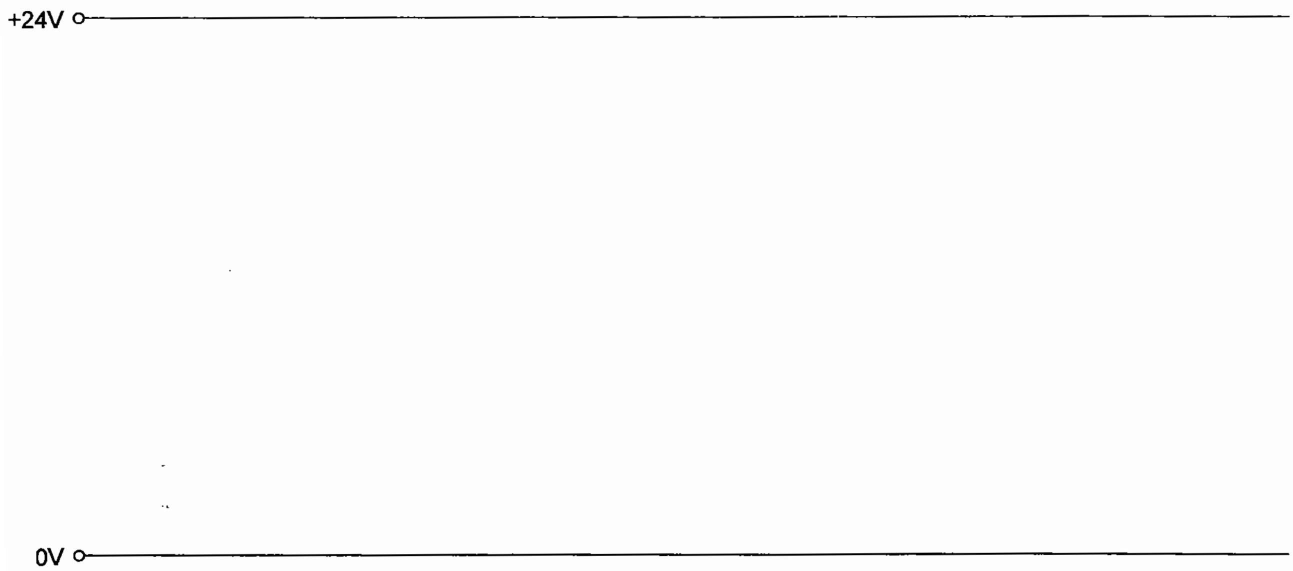


Fig. 6/4:
Signal control, electrical

Fig. 6/5:
Signal control, electrical



WORKSHEET

Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	
IA BASIC	
IA JUMP	
IA MAX	
IB BASIC	
IB JUMP	
IB MAX	
DITHERFREQ	

Conclusion

What conditions must be specified in the process sequence in order to facilitate the acceleration for the hydraulic drive by means of a proportional pressure relief valve?

Subject

Proportional hydraulics

Title

Honing machine

Training aim

- To be able to realise the oscillating movement of a honing machine by means of a proportional hydraulic control system.

Problem definition

- Familiarising yourself with the exercise using the positional sketch, displacement-time diagram and problem description.
- Designing the hydraulic circuit diagram.
- Defining the required signal generator in the displacement-time diagram.
- Drawing up the sequence table.
- Designing the electrical signal control.
- Constructing the complete proportional hydraulic control system.
- Commissioning:
  - Harmonising the proportional directional control valve and the proportional amplifier.
  - Adjusting the linear potentiometer.
  - Setting the threshold value generator of the comparator card.
  - Setting the honing speed by means of setpoint values.
  - Setting the reversing process by means of ramps.
  - Fine tuning of all of the above points.

Problem description

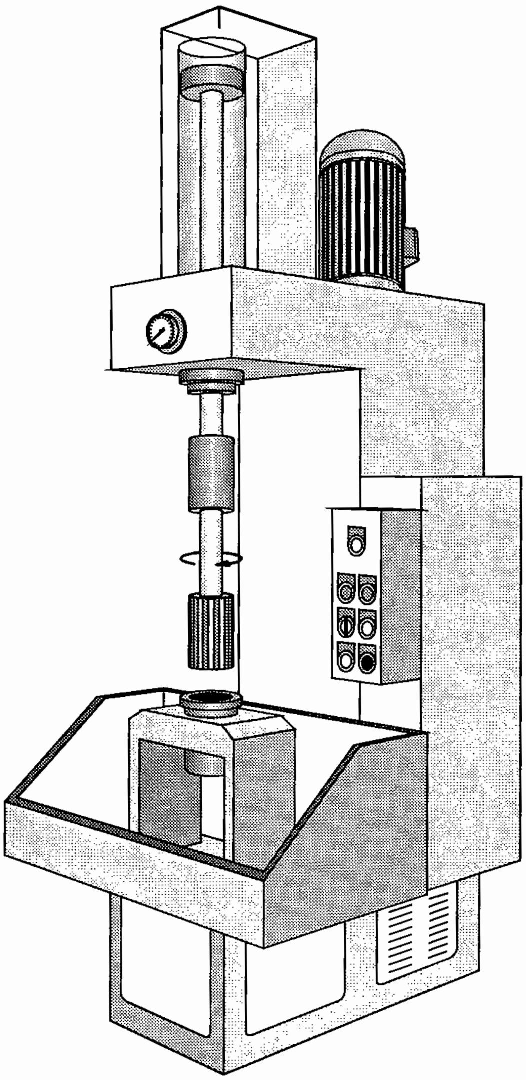
Honing machines are used to surface finish bored holes. It must be possible to achive optimum adaptation of the motion sequences to the machining conditions.

Required are: Standard and short stroke honing with infinite relocatable reversing points and accurate reversing accuracy, plus high adjustable honing speeds.

The reversing process is to be quick, but nevertheless smooth running.

The honing should be adjustable, whilst it should also be possible to terminate manually. On completion of the honing, the hydraulic drive is to return smoothly to its initial position.

Fig. 7/1:
Positional sketch



WORKSHEET

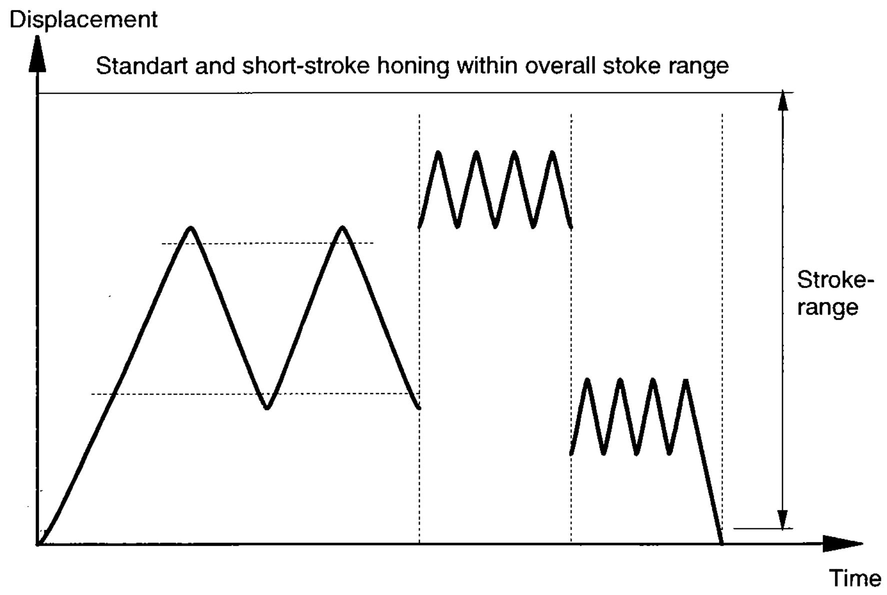


Fig. 7/2:
Signal generator in displacement-time diagram

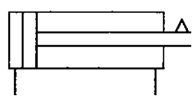


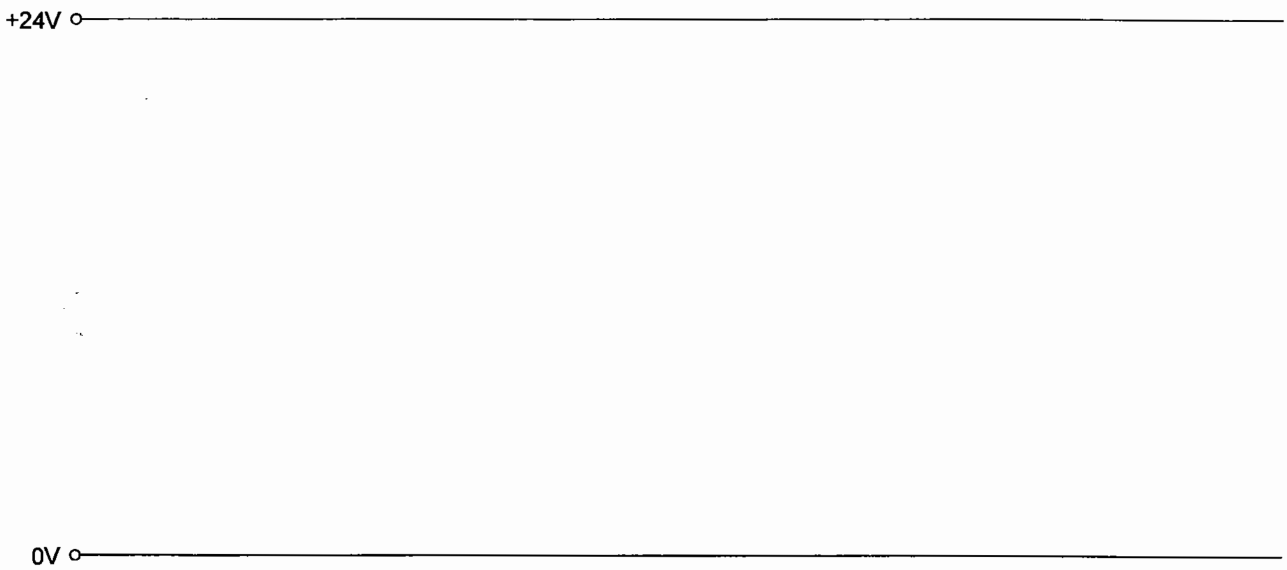
Fig. 7/3:
Circuit diagram, hydraulic

Sequence table

Step	*Sequence*	*Signal generator*	*Setpoint value*	*Setpoint value polling*			*Ramp*	*Comment*
			+ → 1Y1 *- → 1Y2*	*I1*	*I2*	*I3*		
Setting operation	Advancing/ retracting with optional stops							
Automatic 1	Approach and honing start							
2, 4 ...	Honing return stroke							
3, 5 ...	Honing forward stroke							
n	Continuous operation STOP							
n+1	Soft stop							
n+2	Initial position							

WORKSHEET

Fig. 7/4:
Signal control, electrical



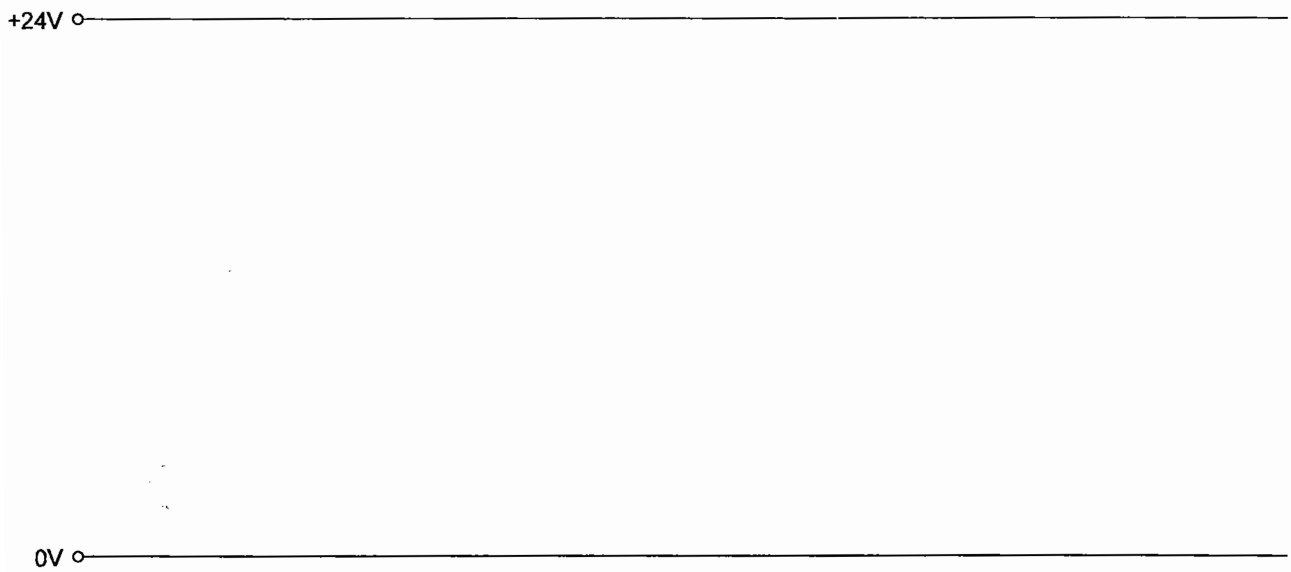


Fig. 7/5:
Signal control, electrical

WORKSHEET

Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	
IA BASIC	
IA JUMP	
IA MAX	
IB BASIC	
IB JUMP	
IB MAX	
DITHERFREQ	

Conclusion

How is it possible to carry out a smooth reversal of direction during an oscillating motion in proportional hydraulics?

Subject

Proportional hydraulics

Title

Moulding closing device

Training aim

- To be able to realise a required **speed pattern** with **soft stop** by means of an additional **bypass circuit**.

Problem definition

- Familiarising yourself by means of the positional sketch, speed-time diagram and problem description.
- Designing the hydraulic circuit diagram.
- Defining the required signal generators in the speed-time diagram.
- Drawing up the sequence table.
- Designing the electrical signal control.
- Constructing the complete proportional hydraulic control system.
- Commissioning:
  - Harmonising the proportional directional control valve and proportional amplifier.
  - Adjusting the signal generator.
  - Setting the required cylinder speed by means of setpoint values.
  - Setting the acceleration and delays by means of ramps.
  - Fine-tuning all of the above points.

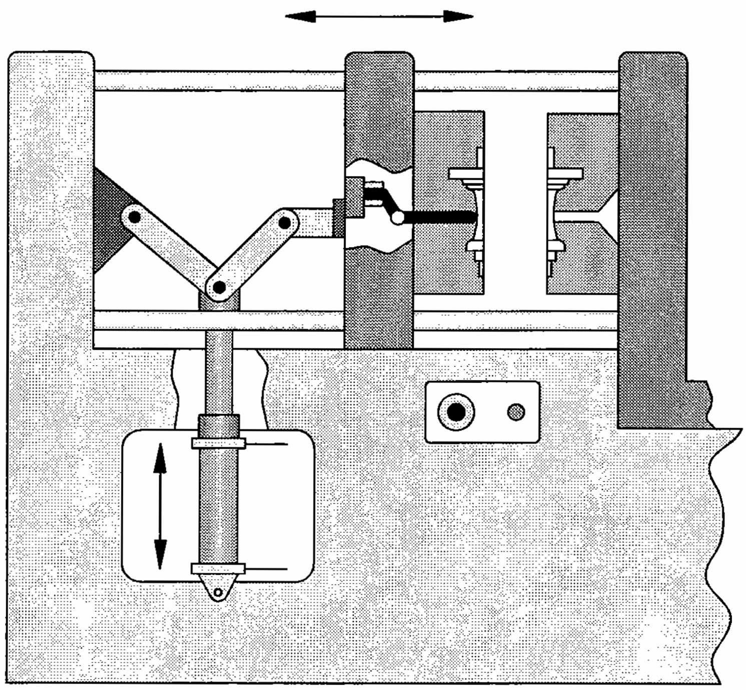
Problem description

A mould closing unit for an injection moulding machine is to be opened and closed by means of a toggle lever mechanism. The mechanism is to be actuated by a double-acting hydraulic cylinder.

In order to achieve a short cycle time, 90% of the closing process is to be effected at high speed. The last part of the closing movement is to be decelerated to a low speed, thereby producing a high closing force. When the injection moulding time has elapsed, the mould closing unit is to be gently opened and returned at high speed. The initial position is reached with a soft stop.

In order to obtain an optimum pump design with regard to large volumetric flow rate and effective pressure, the hydraulic control system is to be designed with an interruptable bypass circuit.

Fig. 8/1: Positional sketch



WORKSHEET

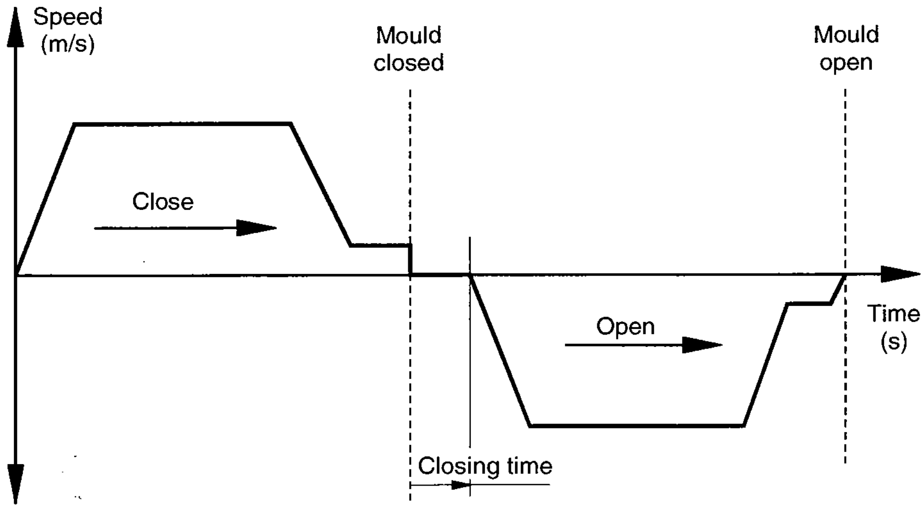


Fig. 8/2:
Signal generator in V-t diagram

Fig. 8/3:
Circuit diagram, hydraulic

Sequence table

Step	Sequence	Signal generator	Setpoint value + → 1Y1 - → 1Y2	Setpoint value polling I1	I2	I3	Ramp	1Y3	Comment
1	Acceleration to high closing speed								
2	Deceleration to closing speed High closing force								
3	Holding of closed mould								
4	Acceleration to opening speed								
5	Deceleration to creep speed								
6	Deceleration in end position								
7	Initial position								

WORKSHEET

Fig. 8/4:
Signal control, electrical

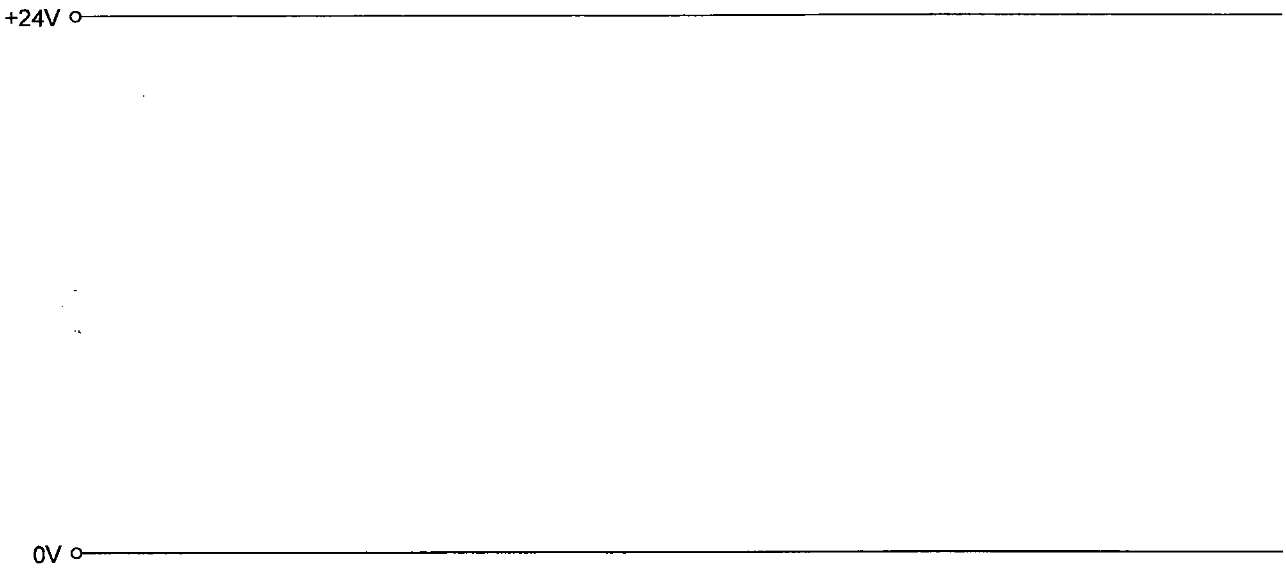
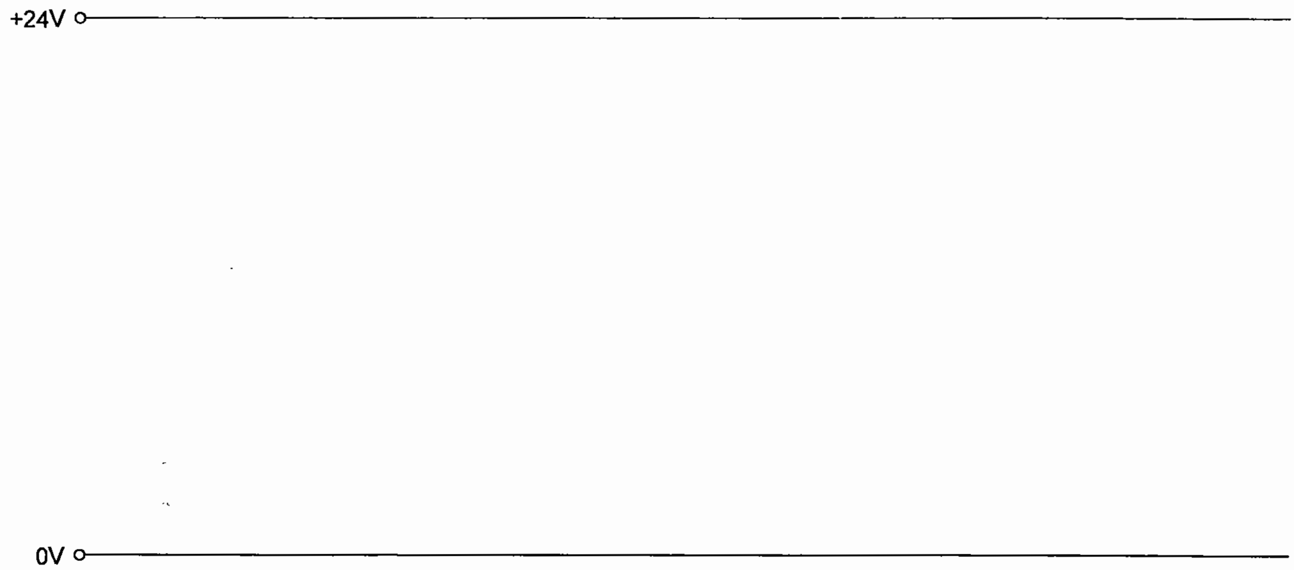


Fig. 8/5:
Signal control, electrical



WORKSHEET

Harmonization of amplifier card

Selector switch	*Display*
FUNCTION	
IA BASIC	
IA JUMP	
IA MAX	
IB BASIC	
IB JUMP	
IB MAX	
DITHERFREQ	

Conclusion

What is the advantage of the hydraulic bypass circuit in the exercise set?

Subject: *Proportional hydraulics*

Title: **Injection moulding machine**

Training aim

- To be able to realise an **injection moulding process** using a worm motor and injecting cylinder by means of **a 2/2-way proportional flow control valve** and a **proportional pressure relief valve**.

Problem definition

- Familiarising yourself with the exercise using the positional sketch, speed/pressure characteristics diagram and problem description.
- Designing the hydraulic circuit diagram.
- Defining the time and process-controlled steps.
- Drawing up the sequence table.
- Designing the electrical signal control.
- Constructing the complete proportional hydraulic control system.
- Commissioning:
  - Harmonising the proportional flow control valve, proportional pressure relief valve and proportional amplifier.
  - Adjusting the signal generator.
  - Setting the required speeds, velocities and pressure levels by means of setpoint values.
  - Setting the acceleration and deceleration by means of ramps.
  - Fine-tuning of all of the above points, including harmonization of the amplifier.

Problem description

An injection moulding machine is used to produce rubber and plastic parts. The hydraulic drive is controlled in such a way that the plasticizing speed and injection pressure produce an optimum injection moulding process.

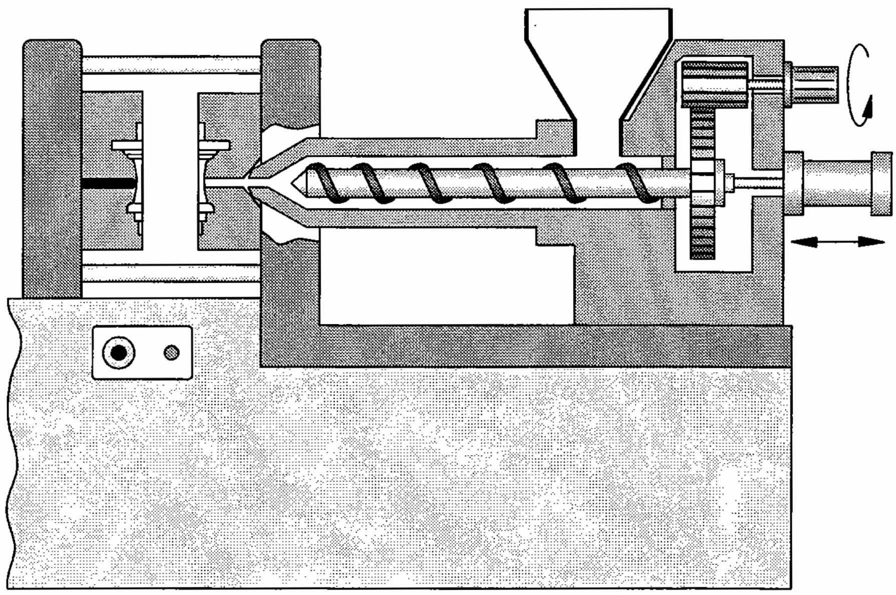
A hydraulic motor drives the worm, which plasticizes the plastic granulates due to thermal effect. The rotary speed characteristics are defined according to the plasticizing process, thereby creating pressure for the return stroke of the injecting cylinder. The hydraulic counter pressure is controlled in such a way as to achieve an optimum plasticizing process.

The plasticized granulate is then injected, whereby the injecting speed and pressure have corresponding characteristics.

After the injection phase, the hydraulic pressure is briefly raised to a specified consolidating pressure level.

Once the granulates have been injected, a new plasticizing and injection moulding process begins; in our example, this is started manually.

Fig. 9/1:
Positional sketch



WORKSHEET

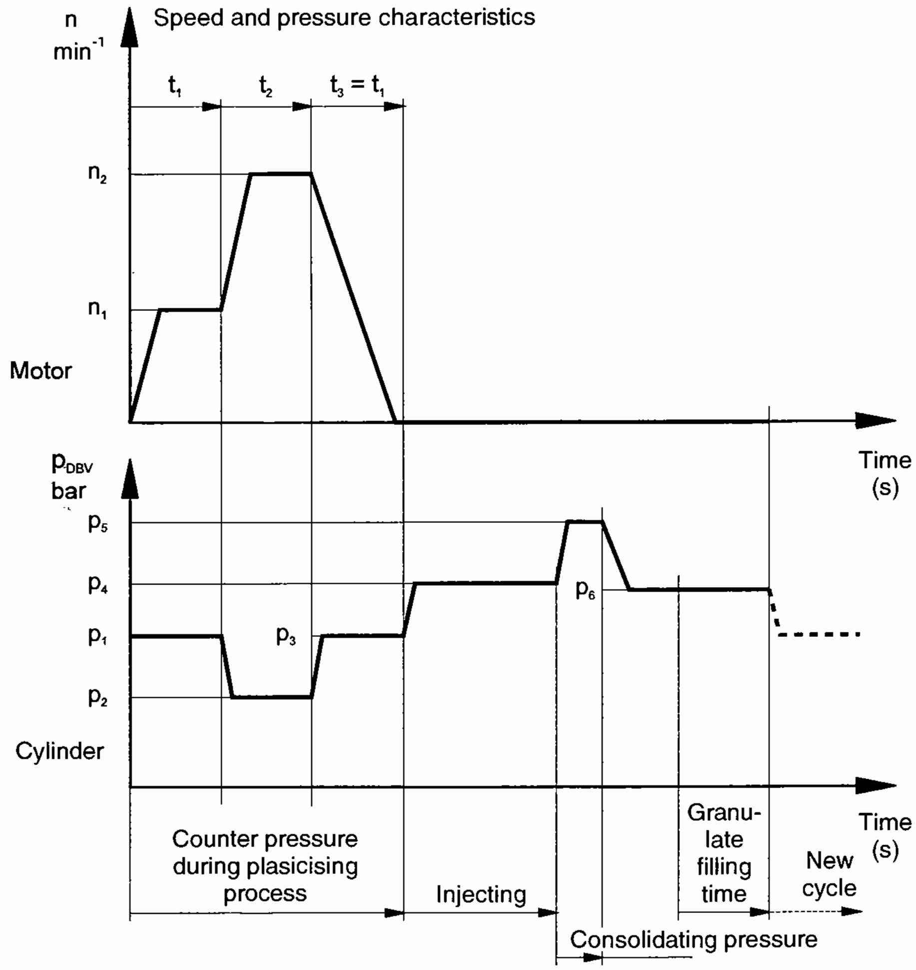


Fig. 9/2:
Signal generator in diagram

Fig. 9/3:
Circuit diagram, hydraulic

WORKSHEET

Proportional flow control valve

Sequence table

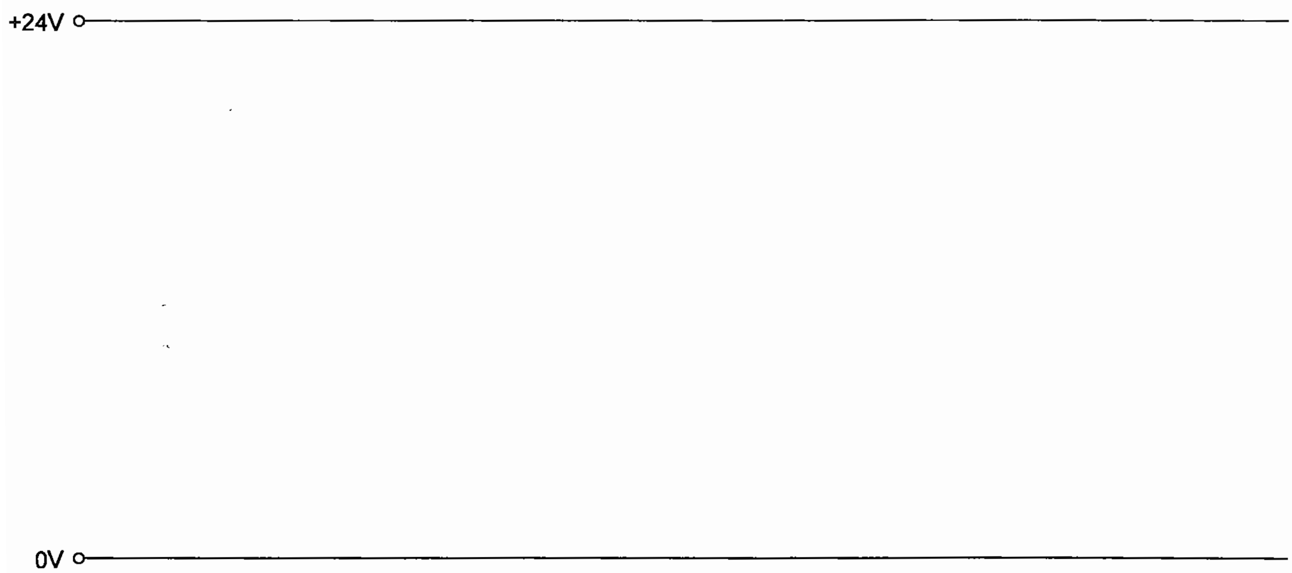
Time and process oriented sequence		*Setpoint value*	*Setpoint value polling*					
Step-No.	*Sequence*	*1Y1*	*I1*	*I2*	*I3*	*Ramp*	*1Y3*	*Comment*
1	Accelerate motor to n1							
2	Accelerate motor to n2							
3	Decelerating motor to standstill							
4	Accel. injecting cyl. to V1							
5	Accel. injecting cyl. to V2							
6 Initial pos.	Cylinder advanced							

Proportional pressure relief valve

Sequence table

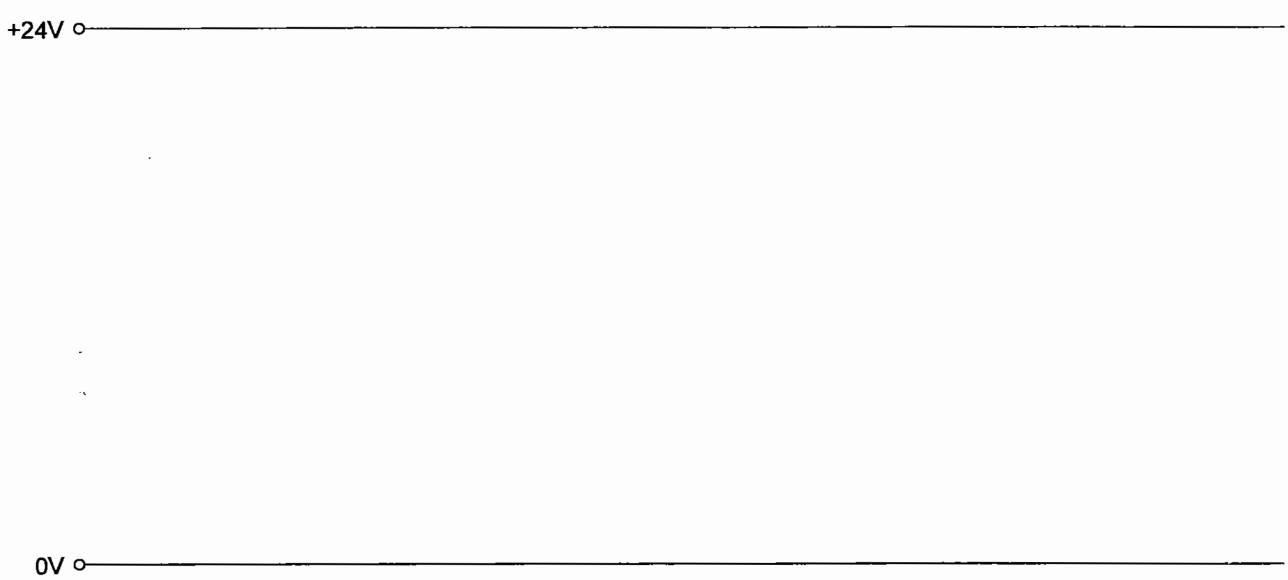
Time and process oriented sequence		*Setpoint value*	*Setpoint value polling*					
Step-No.	*Sequence*	*1Y1*	*I1*	*I2*	*I3*	*Ramp*	*1Y3*	*Comment*
1	Counter pressure 32 bar							
2	Counter pressure 20 bar							
3	Counter pressure 30 bar							
4	Injection moulding pressure to 45 bar							
5	Injection moulding pressure to 57 bar							
6 Initial pos.	Counter pressure 40 bar							

Fig. 9/4:
Signal control, electrical



WORKSHEET

Fig. 9/5:
Signal control, electrical



Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	
IA BASIC	
IA JUMP	
IA MAX	
IB BASIC	
IB JUMP	
IB MAX	
DITHERFREQ	

Conclusion

Under what conditions is it possible to control several hydraulic drives in a system using a proportional flow control valve?

Subject

Proportional hydraulics

Title

Injection moulding machine with mould closing device

Training aim

- To be able to link two individual processes into one **overall process.**
- To be able to effect an optimum interconnection of proportional flow control valves.

Problem definition

- To carry out the exercise with the help of exercise 8 “mould closing device” and exercise 9 “injection moulding machine”.
- Representing the overall process in function chart.
- Designing the electrical signal control to link the two individual processes of mould closing and injection moulding into one overall process.
- Integrating the logic operation stage and commissioning the overall installation.
- Completing the exercise sheet “Proportional flow control valves”.

Problem description

The two individual installations “mould closing device” and “injection moulding machine” from exercises 8 and 9 are to be linked in such a way as to create one overall process.

To achive this, the signal control needs to be amended and a corresponding interface connection designed and integrated.

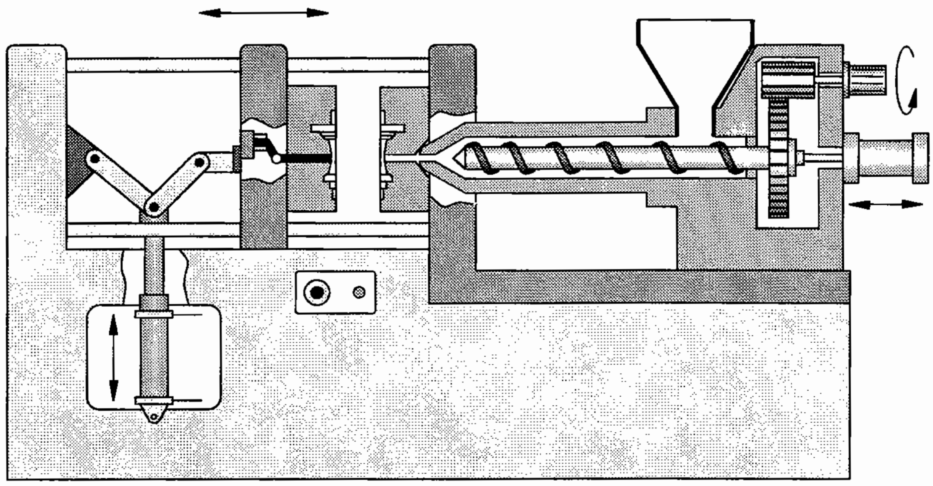


Fig. 10/1: Positional sketch

WORKSHEET

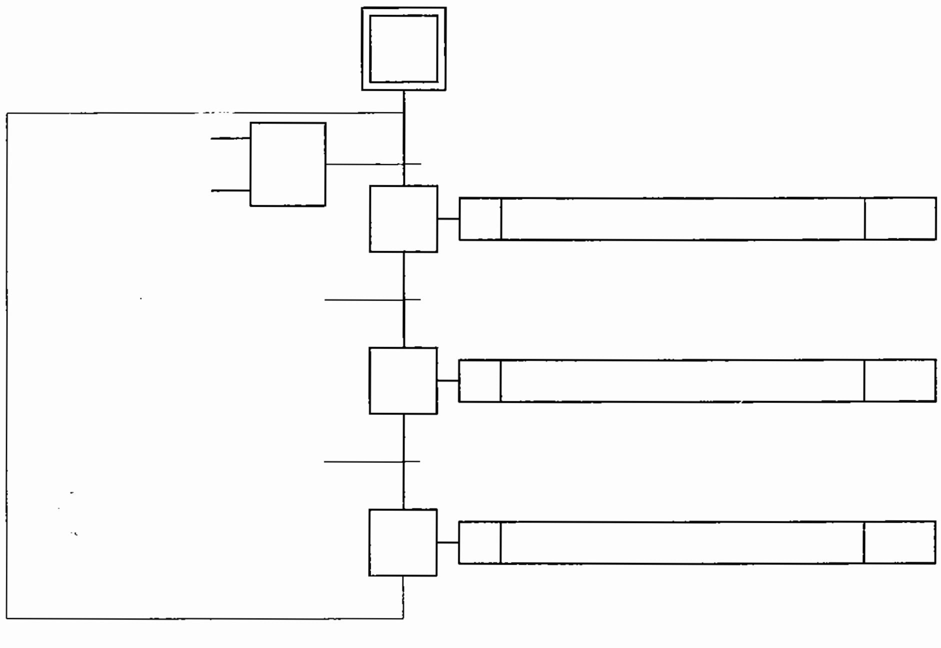
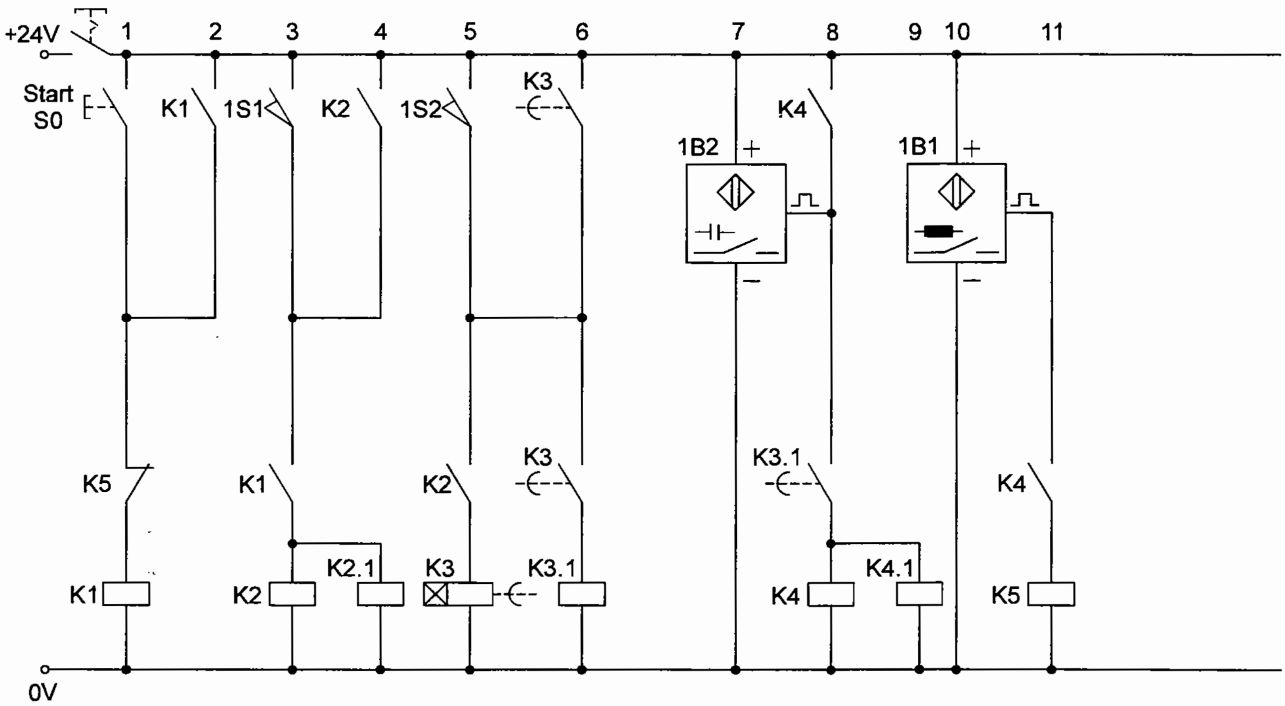
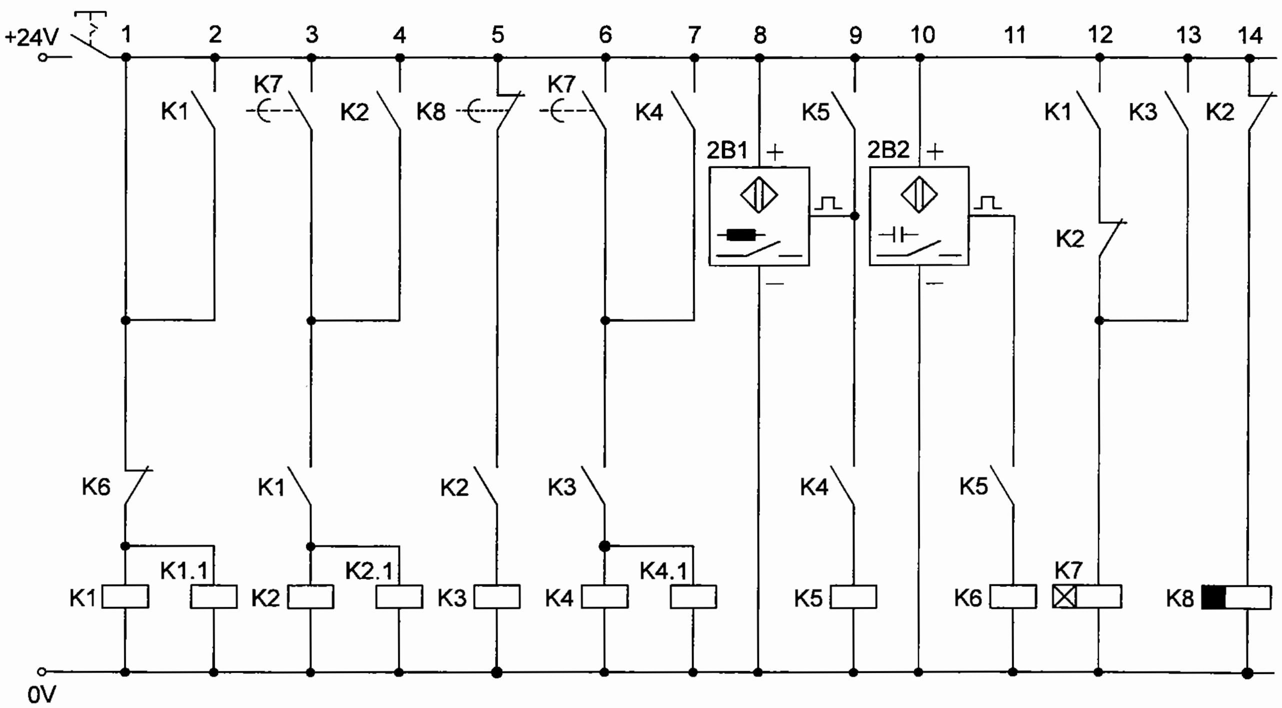


Fig. 10/2:
Function chart

Fig. 10/3:
Signal diagram, electrical



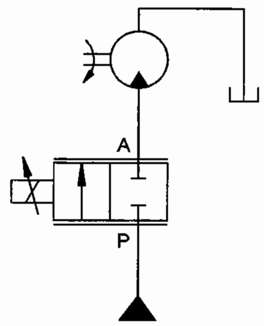
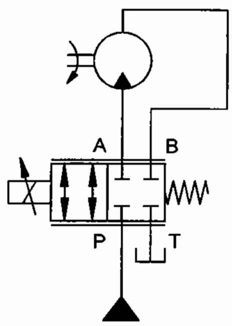
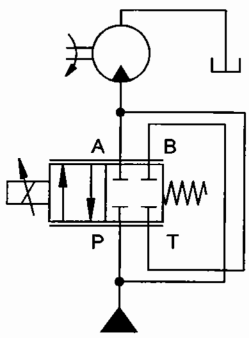


WORKSHEET

Conclusion

Why should the correlations in regard to a control task first of all be considered and recorded neutrally, e.g by means of a function chart or function diagram?

- Describe the functions of the proportional flow control valves in the circuits below.
- Design the same circuit diagram with the help of the 4/3-way proportional valve from the equipment set TP702.

Circuit diagram with 2/2-way proportional valve and 4/2-way proportional valve	*Description*	*Circuit diagram with 4/3-way proportional valve*
		
		
		

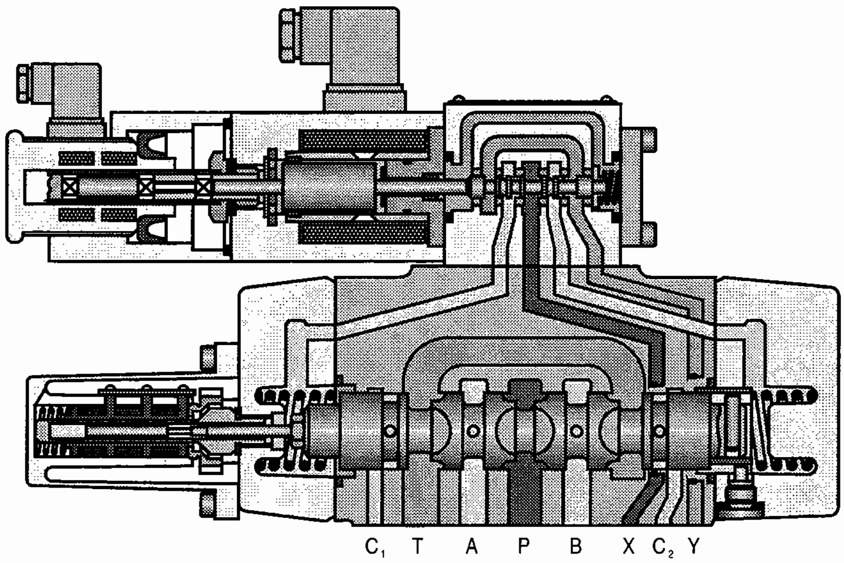
Section B – Fundamentals

The theoretical fundamentals for the training package Proportional Hydraulics are summarised in the following textbook:

Learning System for Automation and Communications

Proportionalhydraulics

Basic Level TP701



Section C – Solutions

Pressure sensor

Plotting of characteric curve

Solution description

The characteristic curve for the entire measuring range of 0 – 100 bar is possible by connecting the hydraulic cylinder in the form of a pressure intensifier.

Cylinder characteristics from the data sheet:

Maximum permissible pressure:	120 bar
Piston diameter:	16 mm
Piston rod diameter:	10 mm

A surface ratio of piston to annular surface of 1.641 is obtained. The maximum adjustable limiting pressure on the hydraulic power pack is 60 bar or at the most 61 bar, so that the intensified pressure can be adjusted up to

$$61 \text{ bar} \cdot 1{,}641 \approx 100 \text{ bar}$$

The maximum permissible operating pressure of the pressure sensor is thus not exceeded. In the static range the pressure should not exceed 3/4 of the full scale value. Therefore a maximum pressure of 75 bar is the upper limit for a plot of the characteristic line.

The accuracy of the plotted characteristic line is dependent on the precision of the measuring devices used and the accurate implementation of the test.

Measuring of input variable

When plotting the characteristic line, the input variable of the pressure sensor is measured by means of a pressure gauge. Pressure gauge characteristics from the data sheet:

Measuring range:	0 – 100 bar
Measuring accuracy:	± 1.6 % corresp. to. Kl 1.6 Tolerance is ± 1.6 % of maximum scale reading across the entire measuring range

Measuring of output variable

The comparator card is intended for the measurement of the output variable. To do this, the selector switch is set to IN A, and the electrical voltage of the pressure sensor applied to input A.

The measuring circuit and the measuring devices used, are generally adequate for an on-the-spot functional check.

Evaluation of characteristic line

The diagram produces the following characteristics:

Input range:	100 bar
Output range:	0-10 Volt
Measuring range:	100 bar, adequate also for pressure intensification
Hysteresis:	The reduced hysteresis is a favourable characteristic of the pressure sensor (not specified in the data sheet).
Linear range:	The permissible linear deviation quoted in the data sheet of ± 1.6 % cannot be detected. The linear range extends across the entire characteristic line with origin zero (proportional correlation).

Setting the threshold values

The threshold values (setpoint values) are selected using the selector switch and set by means of the setting knob and the threshold value (setpoint value) set. The setpoint values are to be taken from the value table. The triggered switching operation is displayed via the corresponding LED`s.

Evaluation

Value table

Measured variable and unit	*Measured values*								*Measuring direction*
Pressure p in bar	0	10	20	30	40	50	60	70	
Voltage V in volts	0.0	0.9	1.9	2.9	3.9	4.9	5.9	6.8	rising
Voltage V in volts	0.0	1	2	3	4	5	6	6.9	falling

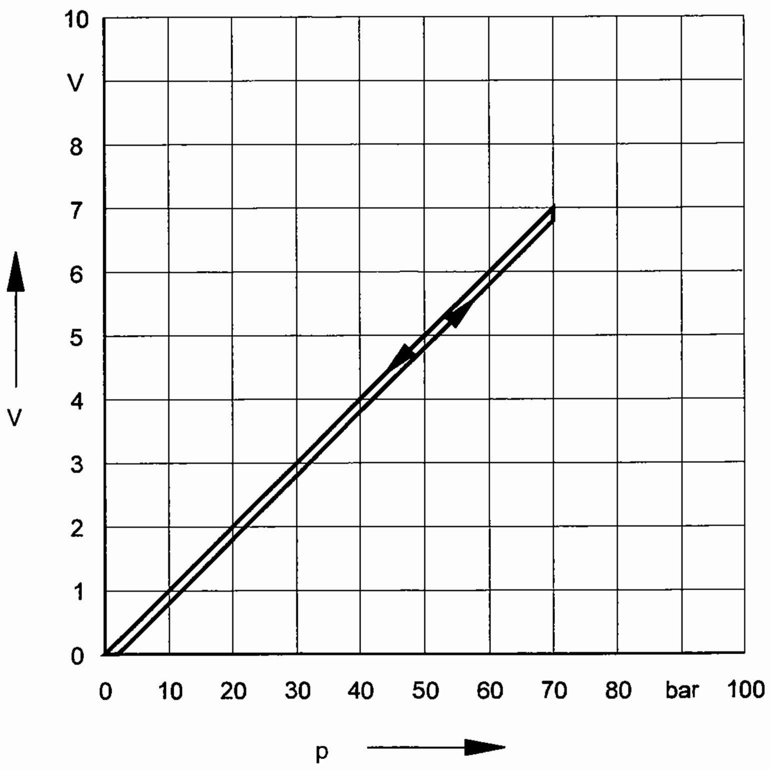


Fig. 1/1:
Characteristic line
Pressure/electrical voltage

Conclusion

Signals/Signal generators

Signal generators of equipment set TP702

Measured variable	*Signal generator*	
	Analogue	*Binary*
Volumetric flow rate* Pressure Temperature Displacement	Volumetric flow sensor Pressure sensor Temperature sensor Displacement sensor	
Position		Proximity sensor. inductive, capacitive and optical Limit switch

* contained in Festo Didactic case only

Binary signals/Binary signal generators

Binary → bivalent

The information form of using two values “On” and “Off” (1 and 0) permits the processing the logic operations and represents the signal processing in control technology.

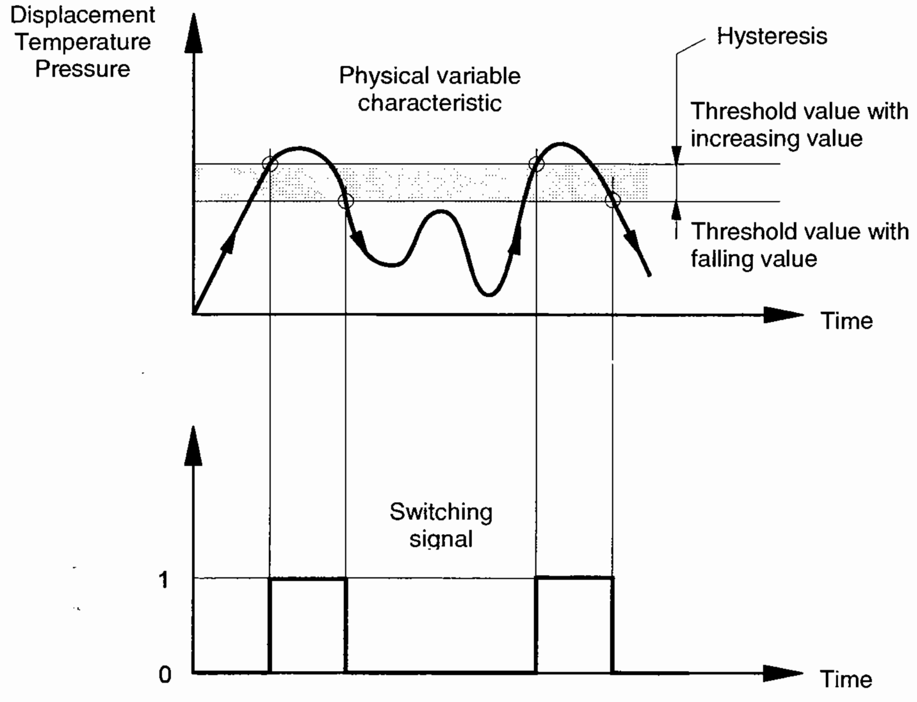
Binary signal generators are limit switches

The physical variable is dtected on a designated value using the so-called limit switches (also known as threshold value indicators). The limit switch supplies a defined signal when the limit switch reaches the set value. If the value is fallen below of, the signal changes to the equivalent value. In control technology, the two values are predominantly allocated 24 Volt and 0 Volt.

Limit value setting

Limit switch:	Positioning during assembly
Pressure switch:	Pretensioning of the spring
Proximity switch:	Positioning during assembly
Comparator card:	Threshold value setting
Push button:	Given by the spring force

Fig. 12:
Function of a limit switch



Switching hysteresis

Switching of the signal from 0 to 1 and vice versa does not take place linearly, but according to a specific difference of the physical variable. The difference is created as a result of the characteristics of the switching device, mainly friction.

In the case of advanced threshold value indicators, such as the Festo Didactic comparator card, the hysteresis value can be set within a large range, whereby the setting value zero is also possible.

The advantages of hysteresis setting facilities manifest themselves, for example, in the case of two-step control, since the switching frequency of the threshold value indicator is halved as a result of the limit value interrogation.

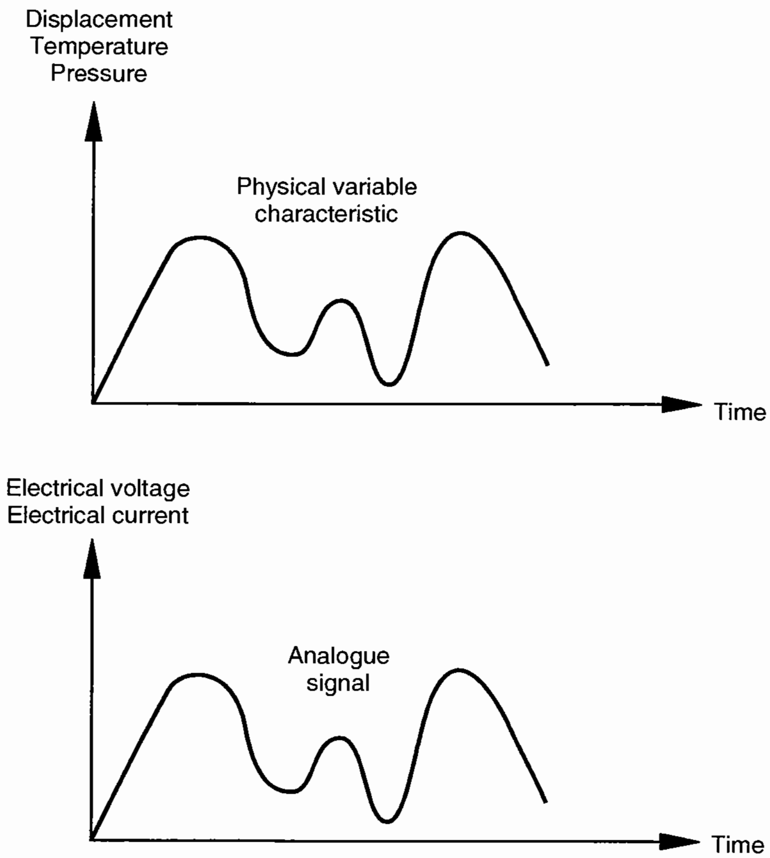
Analogue signals/analogue signal generators

Analogue $\rightarrow$ multivalent

Signal generator function
The signal level continually follows the pattern of the physical variable and always supplies the momentary value, the absolute value.

In the case of the analogue sensors of training package TP702, it is the standard electrical voltage of 0 to 10 Volt.

Fig. 1/3:
Signal pattern



Analogue signal processing is the signal processing of analogue control technology. The current value of the physical variable is continually available for signal processing in the form of a voltage or current signal and is continually processed. The “extra” information is necessary in control technology and requires correspondingly more complex signal processing.

In control technology, analogue signals can be detected at any number of values by means of a threshold value indicator and then processed as a binary signal. Comparator cards are ideal for this.

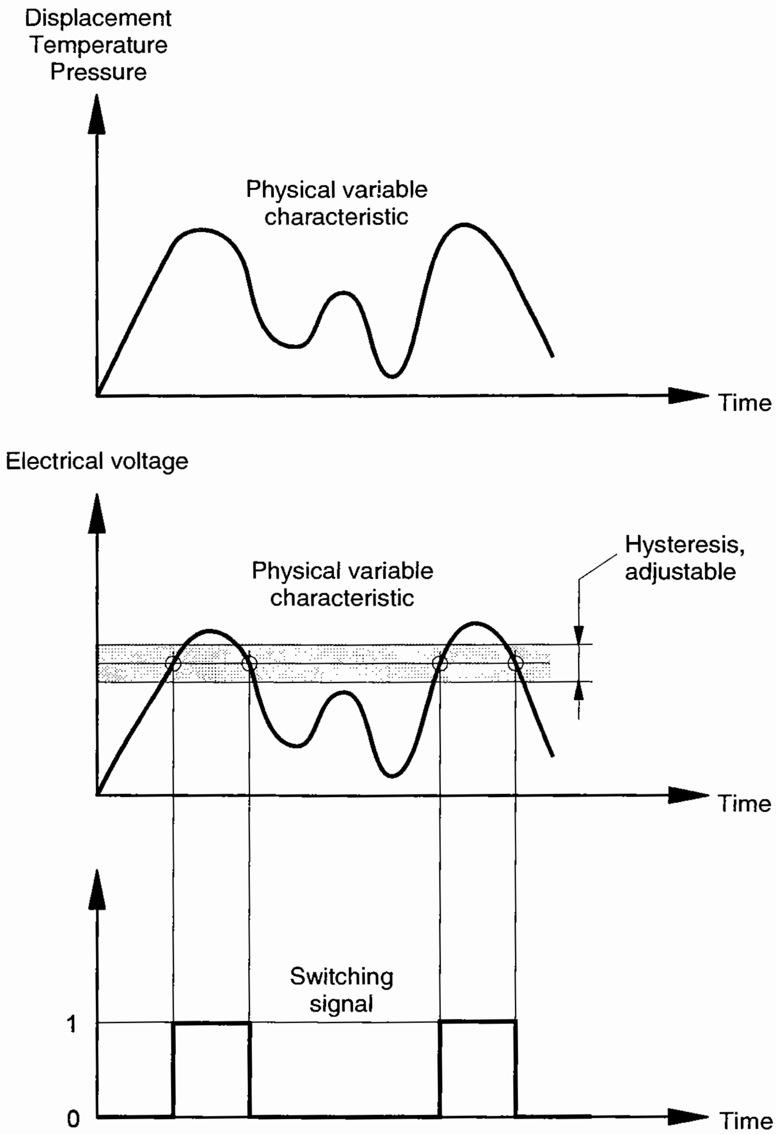
Comparator cards as a universal analogue-to-binary converter and threshold value indicator in control technology.

In control technology, the electrical analogue signals from analogue sensors can be easily detected at any value by means of comparator cards and then processed into binary signals.

The advantages of advanced comparator cards:

- Numerous threshold values can be set.
- Setting can be easily changed.
- Remote control, since the threshold value indicators are connected to the sensor via an electrical line. (A mechanical pressure switch can only be set at the actual point where it is installed.)
- The threshold values can be set more accurately.
- The hysteresis is adjustable. This is an advantage with certain connection methods.

Fig. 1/4:
Function of
Comparator card
(see also data sheet)



Terminology and meaning

Sensors are also known as signal converters, signal detectors, and in connection with closed control loops as measuring transducers or measuring systems. See also the Festo Didactic Workbook TP 511.

Hysteresis, Hysteresis loop

A hysteresis loop is created when the output variable as a function of the input variable is recorded over the whole range. The largest difference of the input variable for an identical output signal is specified as a hysteresis value in a percentage of the maximum signal value in the data sheet.

Linearity

This refers to the maximum deviation between the ideal linear characteristic and the measured characteristic within the linear range. In data sheets, the deviation is specified in a percentage of the maximum signal value.

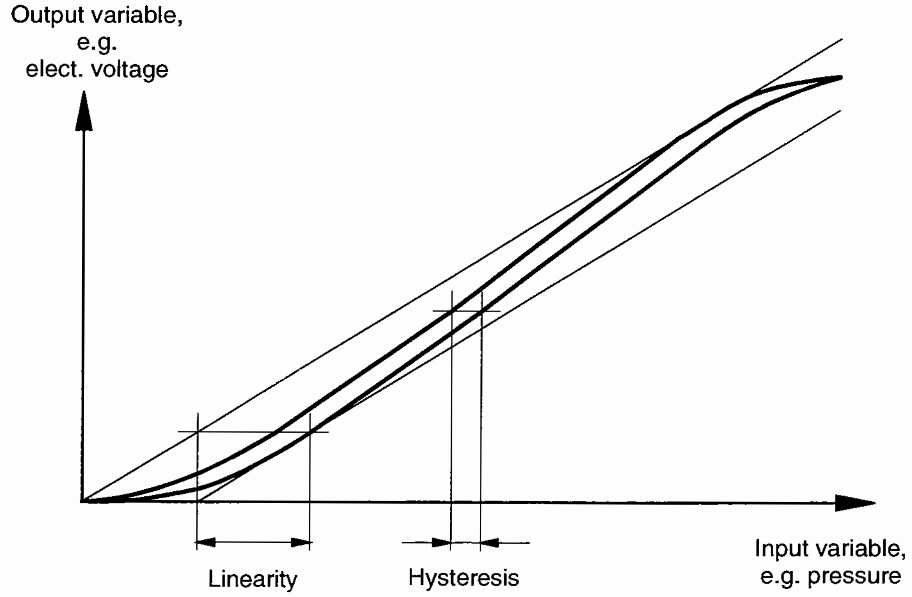


Fig. 1/5:
Hysteresis and linearity

Solution 1

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Double-acting cylinder
1	Pressure sensor
1	Pressure gauge
1	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Comparator card
1	Set of cables

Temperature sensor

Evaluation

Value table

Measured variable and unit	*Measured values*			*Measuring direction*
Temperature T in °C	25	30	40	
Voltage V in volts	2.51	3.01	4.02	rising

Checking of temperature sensor

Solution description

Principle of analogue temperature sensor
This resistance thermometer utilises the analogue allocation of electrical resistance to temperature.
Our sensor is used to detect the temperature using a Pt 100 measuring element, whereby the platinum resistance element used has an electrical resistance of 100 at 0° C. This value is defined as a nominal resistance and described as Pt resistance. Platinum has a positive temperature coefficient. Rising temperature means increasing electrical resistance. The resistance change is converted into a measuring signal electronically and amplified.
The standard voltage 0 - 10 Volt is available analogous to the input range.

Installation
The sensor is built into a hydraulic connector and, like all the other components of equipment set TP702, it can be pressurised up to 120 bar.

The sensor can therefore be used to check or monitor the pump output temperature as an important measuring point or the cylinder input pressure after a flow control action.

Measuring circuit
Our measuring circuit is not intended for the plotting of a characteristic line, but to record the electrical output voltage. This output voltage is also evaluated for the temperature display.

In order to plot a characteristic curve, the temperature would have to be recorded separately. If required, this can be effected with an additional temperature sensor of equipment set TP702. In order to plot a complete characteristic line, the output signal must be recorded with rising and falling temperature. As such, the electrical voltage values deviate from one another in relation to the identical temperature measuring point. If the range is traversed in both directions, this results in a hysteresis loop.

Solution 2

Fig. 2/1: Logigplan

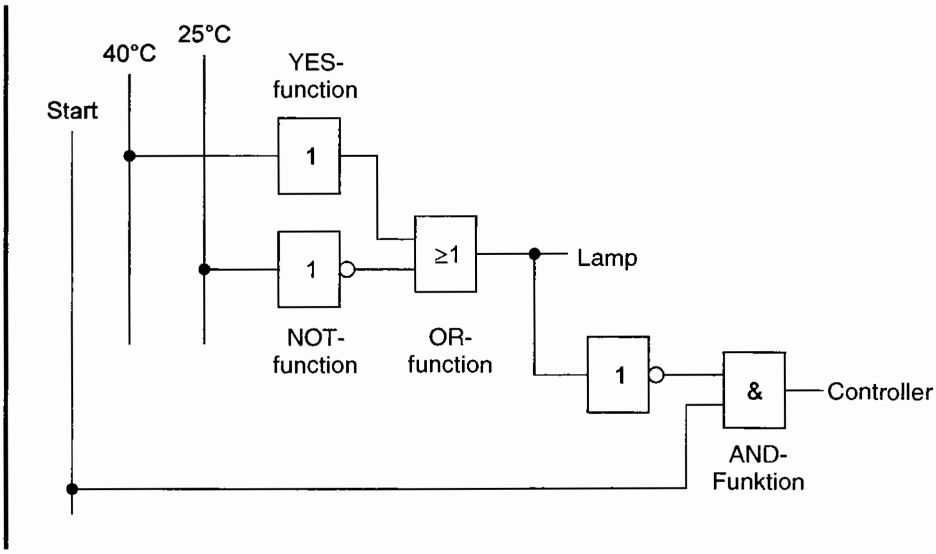
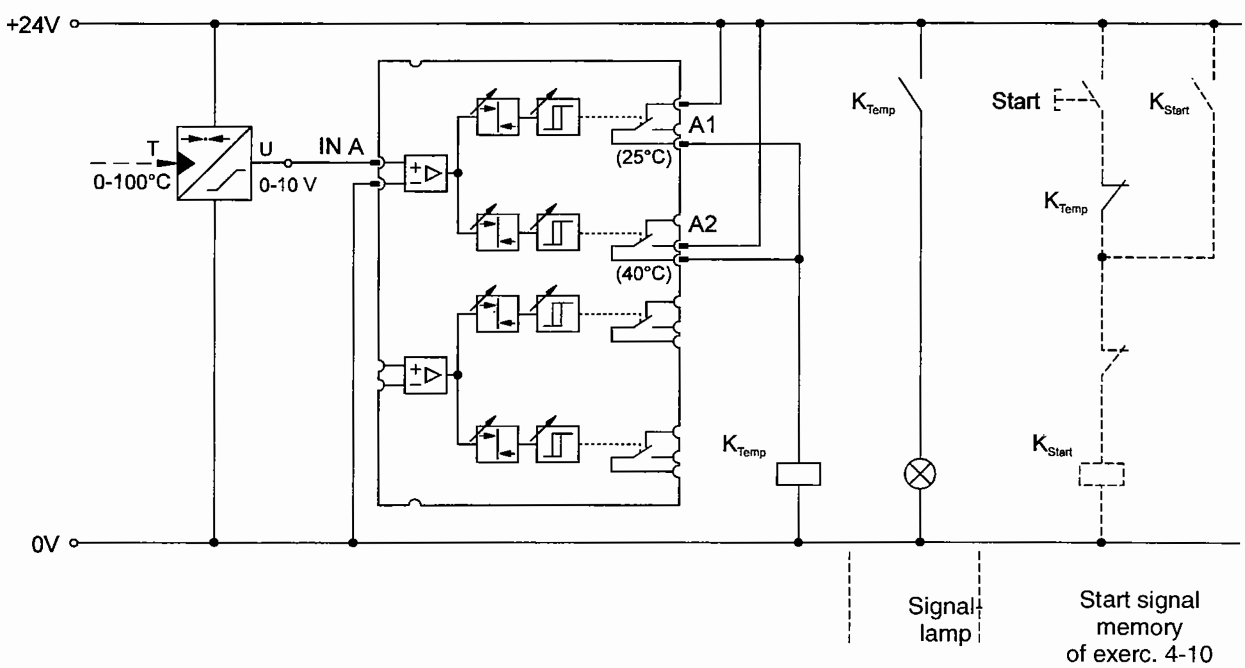


Fig. 2/2: Schaltplan, elektrisch



Temperature monitoring control

Logic

The signal logic operation can be described as follows:

If 25 °C is not achieved, or 40 °C exceeded, the signal lamp is to be illuminated and a re-start is not possible.

A logic diagram enables you to describe the signal logic irrespective of technology. In our solution, the hardware realisation is effected by means of relays and their contacts. The symbols and the logic diagram have been standardised in DIN 40700, Part 14.

Threshold value generator of comparator card

The electrical analogue voltage values to 25 °C and 40 °C have been established by you using approx. 2.5 V and 4.0 V.

These voltage values are now set as threshold values for input "A" of the comparator card. To do this, use the selector switch to select "S A1" for the value 2.5 V or "S A2" for 4.0 V, and set the values with the adjuster.

When the input voltage now reaches these threshold value settings, contacts A1 or A2 will switch. If the input voltage drops below the values set, the contacts will open. (Strictly speaking, the value determined in the falling measuring direction must be taken as the threshold value, when failing to meet the lower limit). In order to bring about the switching and returning with the same voltage value, the hysteresis "H A1" and "H A2" of the comparator card is set at "zero".

See also the operating instructions and technical data in the appendix.

When temperature monitoring in a production system, a range of 40 °C to 55 °C is usual for a steady-state tank temperature. However, these temperatures are not achieved during short-time operation, e.g. such as for training.

Set your own individual values.

Integration of hydraulics, electro-hydraulics and proportional hydraulics in Festo Didactic exercises

You can use the control system for temperature monitoring in all the exercises. Naturally, in the case of hand lever hydraulics, only an optical display is possible.

Conclusion

For ready status monitoring, several limit values must be detected and supplied to a corresponding signal logic.

For example:

Critical upper and lower oil temperature for the cooling circuit, possibly also heating.

A temperature sensor and comparator card represent the ideal means for a solution.

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Flow control valve
1	Temperature sensor
1	Pressure gauge
1	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Universal hand measuring device
1	Comparator card
1	Relay, 4-off change-over contacts
1	Signal lamp (LED)
1	Set of cables

Displacement sensor

Evaluation

Value table

Measured variable and unit	*Measured values*					*Measuring direction*
Cylinder stroke in mm	0 retracted end position	50	100	150	200 forward end position	
Voltage V in volts	0.18	2.5	5.04	7.53	9.99	rising
Voltage V in volts	0.18	2.49	5.02	7.50	-	falling

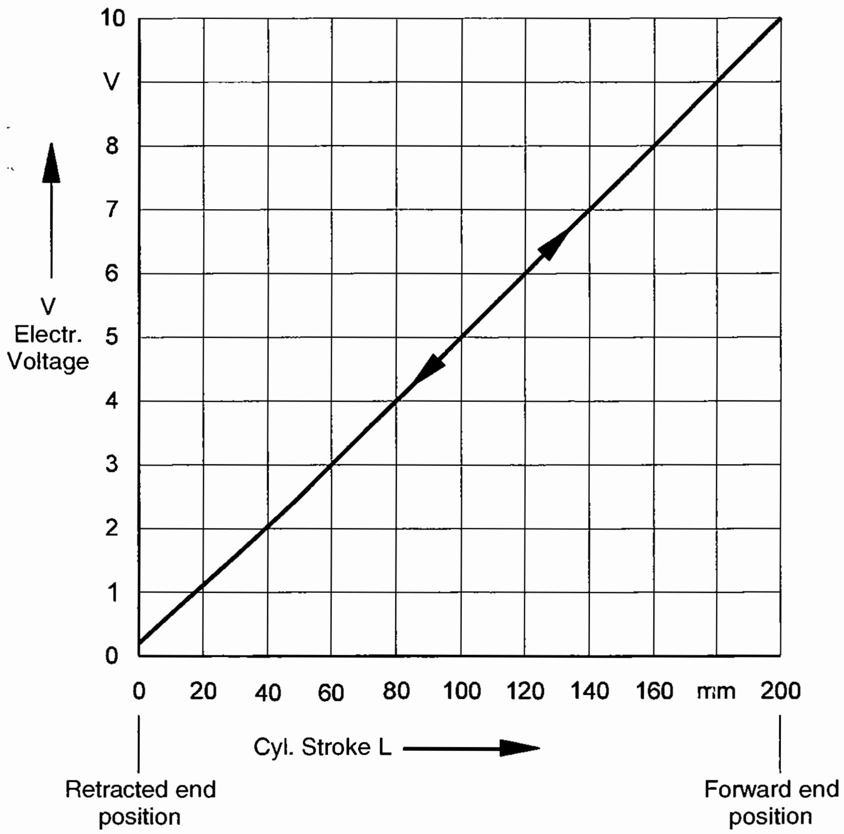


Fig. 3/1: Stroke/voltage characteristic

Evaluation of measuring results:

- The linear range extends across the entire measuring range.
- A hysteresis cannot be detected with the measuring method used.

Solution description

General information regarding the potentiometer

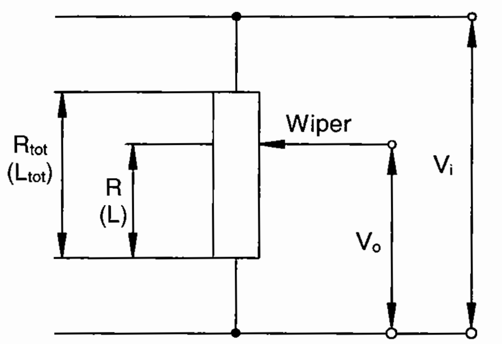
The linear potentiometer converts the physical variable "displacement" into an electrical voltage. This is effected according to the voltage divider principle: On an ohmic resistor R_{tot} with the input voltage V_i, the voltage V_o is tapped via the resistor R at any point:

$$V_o = V_i \cdot \frac{R}{R_{tot}}$$ Voltage divider formula

Since the resistance is proportional to the length L of the potentiometer, this results in:

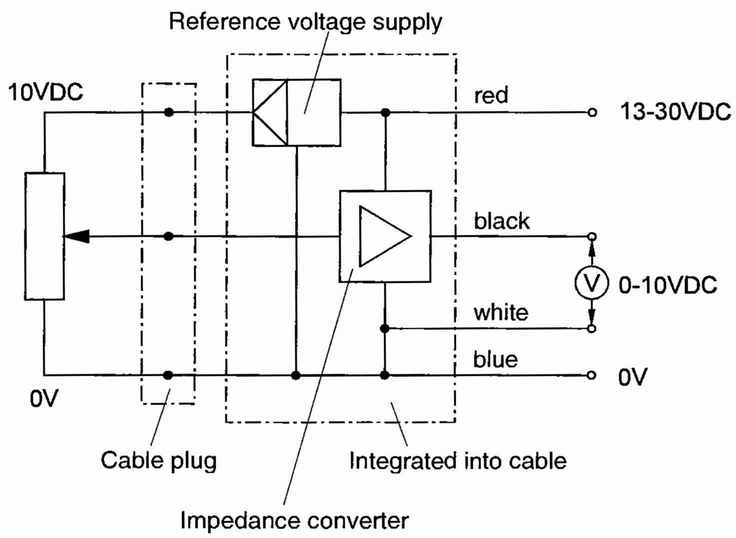
$$V_o = V_i \cdot \frac{L}{L_{tot}}$$

Fig 3/2: Electrical voltage divider



V_i = Input voltage
V_o = Output voltage
R_{tot} = Total resistance
R = Partial resistance
L_{tot} = Total length
L = Wiper position

Fig 3/3: Construction and connection of linear potentiometer



Reference voltage supply

The reference voltage supply is an electronic module, which ensures a high-precision voltage. This voltage is used to supply the potentiometer. Fluctuations in supply voltage do not affect the reference voltage.

Impedance converter

If current passes through a consuming device on the signal output of the linear potentiometer, then the voltage divider is on-load and the tapped voltage therefore changed.

An impendance converter, also known as a isolation amplifier, keeps the potentiometer virtually load-free. The signal voltage remains unchanged.

The impendance converter with protective circuit is casted into the potentiometer cable. At the same time, this circuitry protects the potentiometer from damage when interchanging the connections.

Solution 3

Fig. 3/4:
Circuit diagram, hydraulic

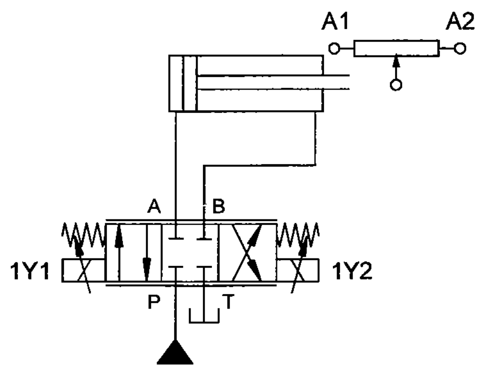
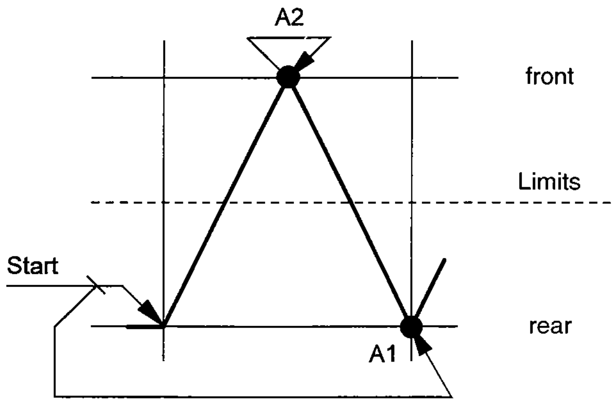


Fig. 3/5:
Displacement-step diagram



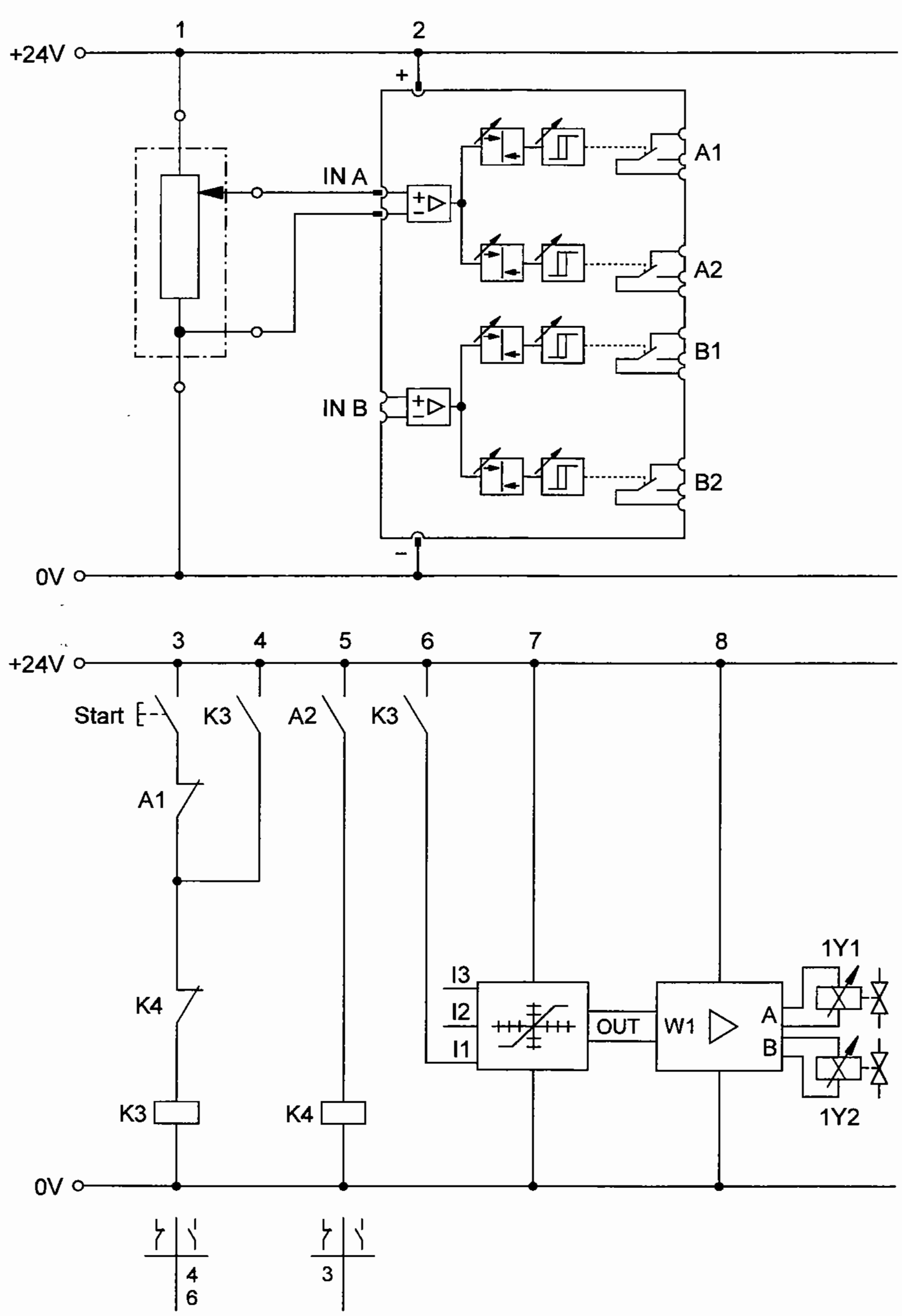


Fig. 3/6:
Circuit diagram, electrical

Basic control for limit sensing by means of displacement sensor and comparator card

Retracted end position

In order for a switching action to be triggered in the retracted end position, a lower than set threshold value is to be recorded. As already described during the assembly of the potentiometer, the potentiometer signal value zero or better still a small voltage value can be emitted at the cylinder end position which, when slightly increased, represents the threshold value.

In our control system, the threshold value indicator A1 with its normally closed contact is used, since the logic operation is a NOT-function: When the set threshold value is NOT reached any longer, then the retracted end position has been reached. The A1 normally closed contact of the comparator card is closed and the required Start precondition is given.

This connection also applies for a retracted position in front of the mechanical cylinder stop.

Forward end position

The signal processing is as usual. When the forward threshold value A1 is reached, its normally open contact closes the relay circuit KA2, thereby initiating the return stroke.

This connection also applies in the case of a forward position in front of the mechanical cylinder stop.

Intermediate switching points

A triggered switching action of the threshold value contacts during advancing remains intact.

This switching action is reset during retracting and when falling below the threshold value.

For limit sensing by means of electrical threshold values, see also exercise 7, honing machine..

Conclusion

At the point of falling below of the threshold value, the threshold value relay is de-energised.

A circuit can be opened or closed by means of the relay contacts.

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Pressure filter
1	Double-acting cylinder
1	4/3-way proportional valve
5	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Proportional amplifier
1	Setpoint value card
1	Linear potentiometer, complete with mounting kit
1	Comparator card
1	Push button “Start”
2	Relay, 4-off change-over contacts
1	Set of cables

Squeezing press

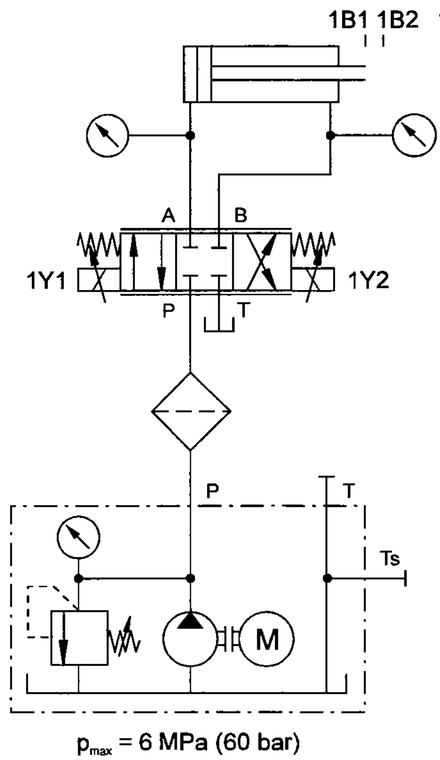


Fig. 4/1:
Circuit diagram, hydraulic

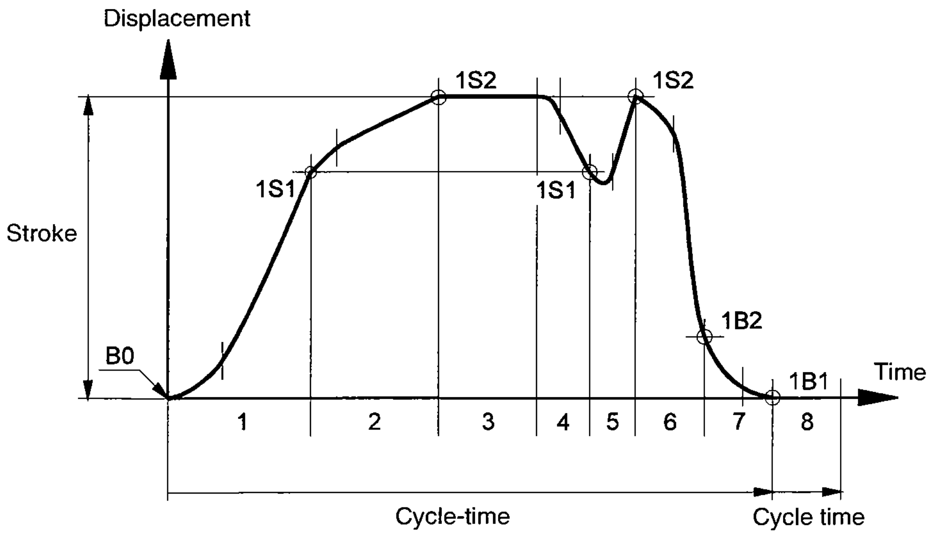


Fig. 4/1:
Signal generator in displacement-time diagram

Solution 4

Sequence table

Step	*Sequence*	*Signal generator*	*Setpoint value* + → *1Y1* - → *1Y2*	*Setpoint value polling* *I1*	*I2*	*I3*	*Ramp*	*Comment*
Setting-operation	Advancing/ retracting with optional stops	Selector switch AUTO/SET	W1 0 bis + 10 V 0 bis - 10 V	0	0	0	Set to "zero"	For commissioning e.g. testing of signal generator position
Auto-matic	Initial position	Selector switch and B1	W 8 – 0.5 volts	1	1	1		Cylinder is pressur-ised in retracted end position
1	Acceleration to stroke speed	Start B0	W2 + 10 volts	1	0	0	R1 0.10 S/1 V	Start via optical sensor
2	Decelerating to creep speed	1S1	W3 + 2.5 volts	0	1	0	R2 0.05 S/1 V	
3	Pressing for curing	1S2	W3	0	1	0	–	Start of time function
4	Acceleration or partial return stroke	Time signal	W4 - 7 volts	1	1	0	R3 0.05 S/1 V	Time expired
5	Smooth reversing action for forward stroke	1S1	W5 + 10 Volts	0	0	1	R4 0.05 S/1 V R1 0.10 S/1 V	Forward stroke to stop without decel-eration
6	Acceleration to return stroke speed	1S2	W6 - 8 volts	1	0	1	R3	
7	Deceleration to creep speed	1B2	W7 – 3.5 volts	0	1	1	R4	
8	Initial position	1B1	W8	1	1	1		

Fig. 4/3:
Signal control, electrical

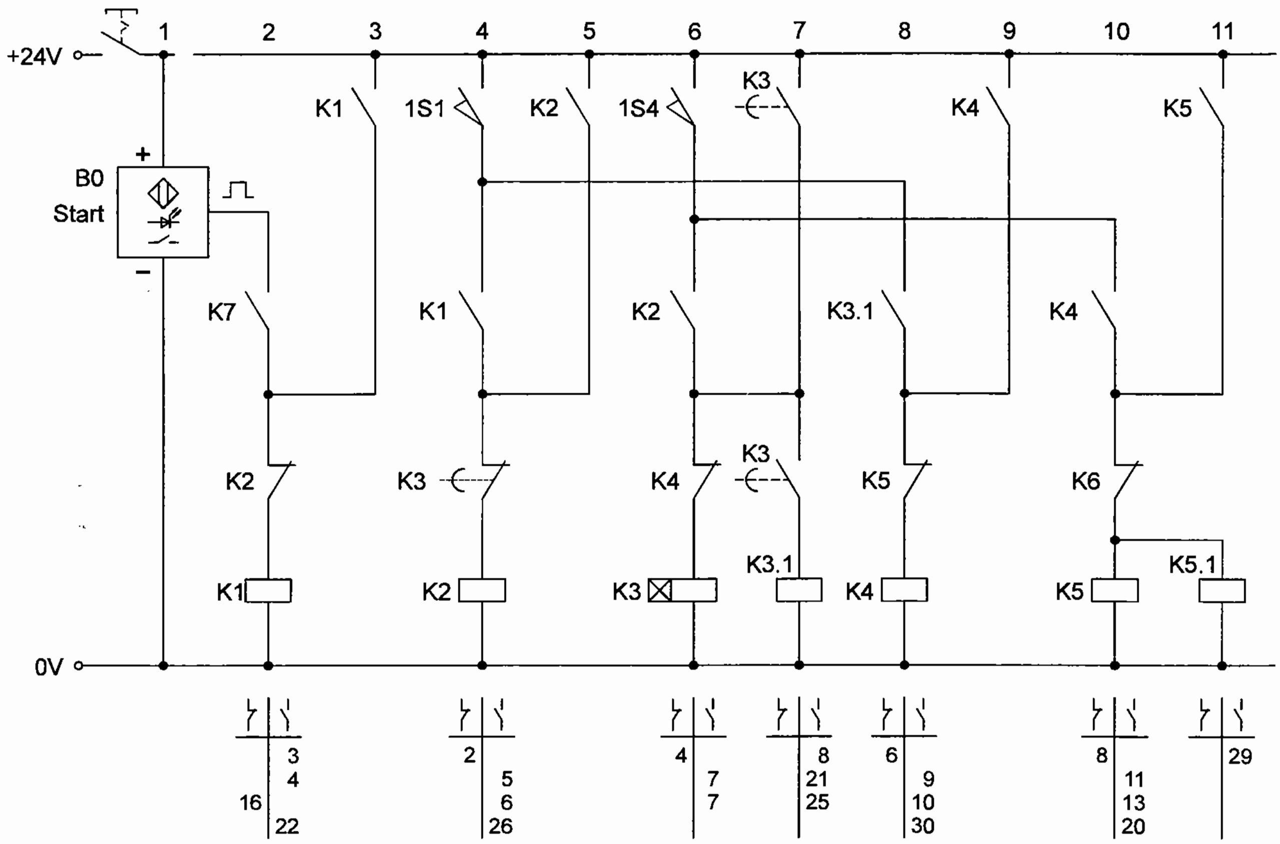


Fig. 4/4:
Signal control, electrical

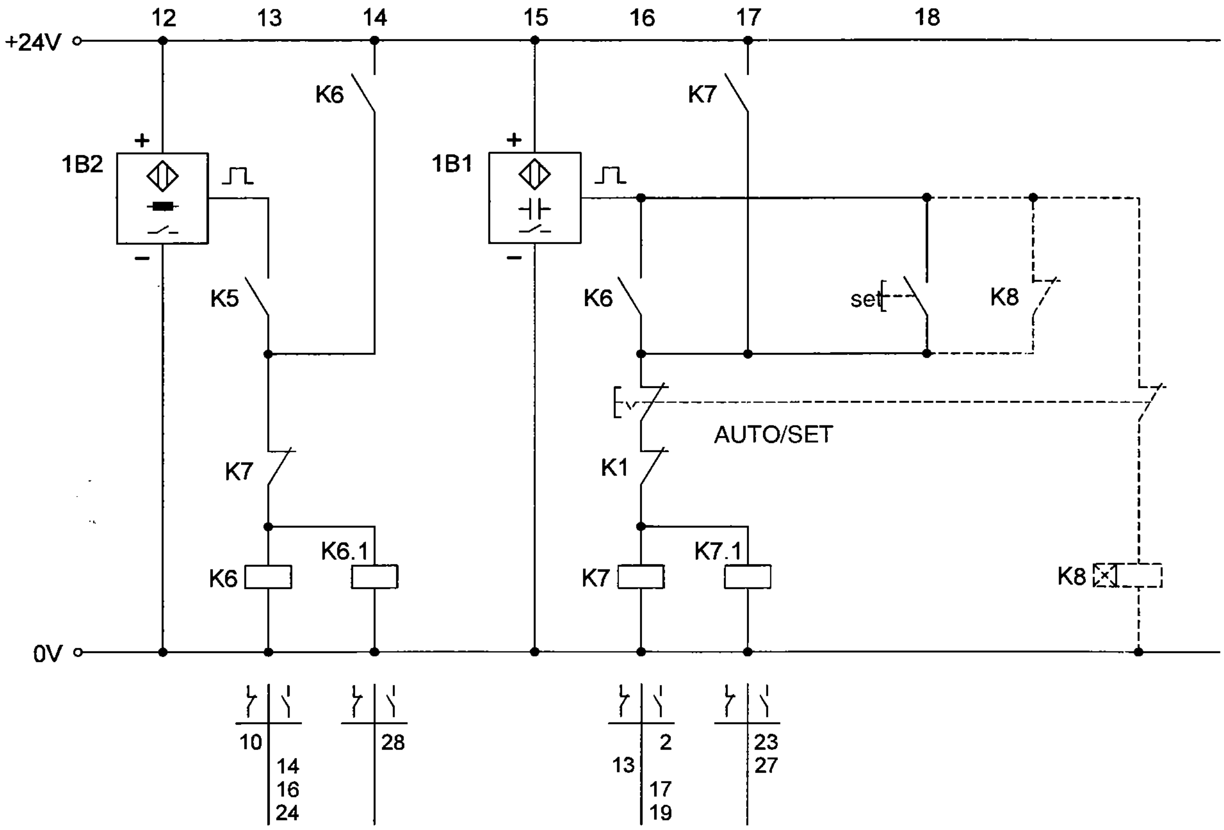
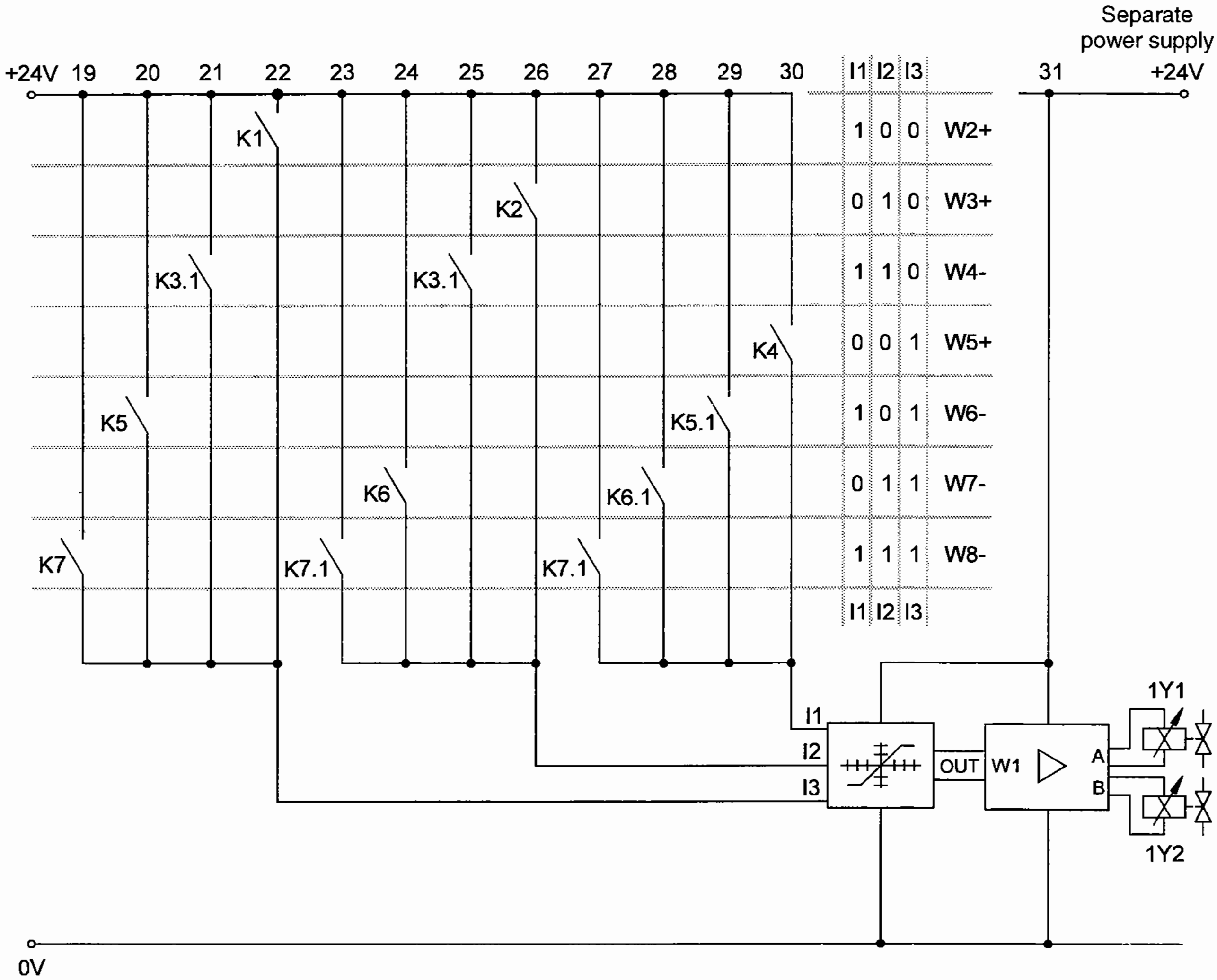


Fig. 4/5:
Signal control, electrical



Solution description

Training content

In this example, the training contents of the workbook TP701, Basic Level, are summarised and covered once more.

The solution method for this more complex problem definition is incorporated into the structure of the problem. Of major importance is the sequence table, which is used to define the individual steps of the signal control. The sequence table thus forms the blue print for the design of the signal control.

Signal generator

Required are signal generators with binary signal function. The connection of the inductive, capacitive and optical sensors can be effected in the intended way, since the signal outputs of the binary sensors from the training package TP702 are fitted with a diode. If allocated as an input, the connection is closed.

Signal control

The type of control required is a process-controlled sequence control. A resetting relay sequencer system is suitable for this, which is used in this exercise.

In this exercise, the setting of a stage in the sequence via the corresponding signal generator means:

- Output signals for setpoint value polling.
- Preparation of subsequent stage.
- Resetting of previous stage.

This also means that for the start, the last (previous) stage must be prepared, i.e. set. If the electrical control energy is switched on, then the previous stage must be set either automatically or by means of a manually set signal, thereby preparing the signal control for the start. An automatic setting process is shown by a dashed line.

The prepared signal control with its output signals produces the output position of the hydraulic drive, which is defined in the sequence table. The setpoint value W8 is switched; the cylinder is pressurised in the retracted end position.

In general, the following procedure applies for the connection of energy:

1. Switch on the electrical control energy.

2. Connect the hydraulic energy.

In our example, the electrical sequencer also needs to be set prior to switching on the hydraulic pump.

For instance, if the sequencer is not set and the hydraulic pump is switched on, then the setpoint value W1 for the setting operation is active. The automatic setting process drawn in a dashed line would of course prevent this.

Construction and commissioning

The proportional hydraulic control is constructed in its entirity.

The signal generators are to be positioned where you think most suitable.

When constructing the relay sequencer control, the respective step can for instance be checked for its set and reset function by means of a manual signal triggering. With the help of the sequence table, it is also possible to easily check the output signals for each step. These must correspond to the bit code for the polling of setpoint values and are displayed by light emitting diodes at inputs I1 to I3 of the amplifier card.

The setpoint values are set approximately in accordance with the designated speeds (e.g.rapid traverse / creep speed). For example, if the highest possible speed is required, a setpoint value of 10 volts is set.

It is recommended to start with the ramp setting “zero”.

It is of course possible to set the values specified in the solution direct.

After this, the first cycle is started and the sequence observed.

The sequential process is optimised by adapting the cylinder speeds, acceleration and deceleration ramps, as well as the positions of the signal generators.

For fine-tuning, the basic and jump current are also of importance. This is described in detail in the preface.

Visually, the motion sequence is to be represented in accordance with the specified displacement-time diagram.

Setting operation

At simple setting operation can be carried out at the end of any cycle with the selector switch AUTOMATIC/ RESET, whereby the last sequence stage is no longer set or reset. The setpoint value W1 with the signal polling code 0/0/0 becomes active. The proportional solenoids 1Y1 and 1Y2 can now be manuaily actuated with and the hydraulic cylinder delicately traversed and positioned.

A changeover in AUTOMATIC mode and setting of the last control stage is only enabled by 1B1 in the initial position.

Conclusion

The optimisation of the sequence motion of an installed proportional hydraulic system is effected by the interaction of the following measures:

- Positioning of the signal generators.
- Setting of the setpoint values.
- Setting of the ramps.
- Fine-tuning of the amplifier.

Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	2-channel amplifier
IA BASIC	0
IA JUMP	50 mA
IA MAX	800 mA
IB BASIC	0
IB JUMP	50 mA
IB MAX	800 mA
DITHERFREQ	200 Hz

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Pressure filter
1	Double-acting cylinder
1	4/3-way proportional valve
2	Pressure gauge
5	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Proportional amplifier
1	Setpoint value card
1	Main switch
1	Push button “Set”
1	Proximity sensor, optical
1	Proximity sensor, inductive
1	Proximity sensor, capacitive
2	Limit switch
10	Relay, 4-off change-over contacts
1	Time relay, with switch-on delay
1	Set of cables

Hydraulic lift

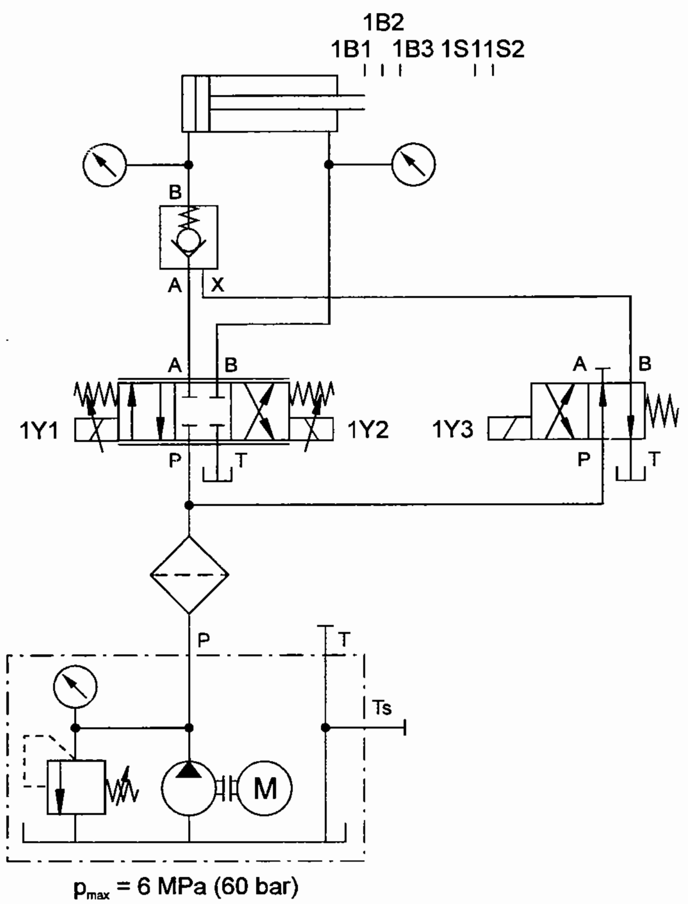
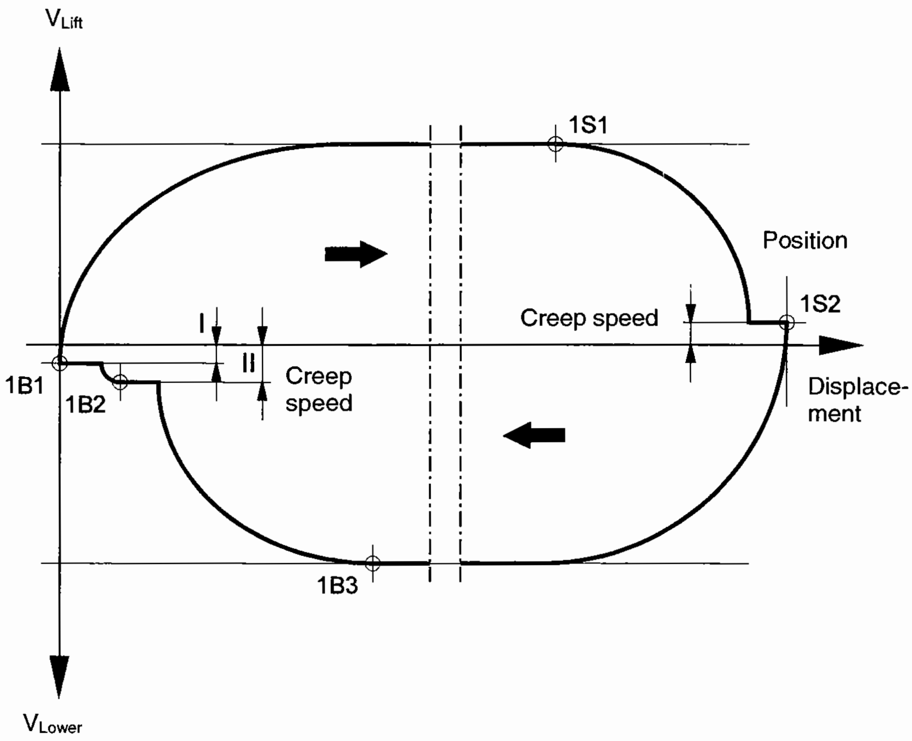


Fig. 5/1:
Circuit diagram, hydraulic

Fig. 5/2:
Signal generator in positioning diagram



Sequence table

Step	*Sequence*	*Signal generator*	*Setpoint value* + → *1Y1* - → *1Y2*	*Setpoint value polling* *I1*	*I2*	*I3*	*Ramp*	*Amplifier output* $\overline{OA}$ *A*	$\overline{OA}$ *B*	*1Y3*	*Comment*
Setting operation	Advancing/ retracting with optional stops	Selector switch AUTO/SET	W8 0 bis +10 V 0 bis - 10 V	1	1	1	Set to "zero"	0	0	1	Commissioning
1	Acceleration to stroke speed	Push button "Lift"	W2 + 10 V	1	0	0	R1 0.05 S/1 V	0	0	0	Lift
2	Deceleration to creep speed	1S1	W3 + 3 V	0	1	0	R2 0.05 S/1 V	0	0	0	
3	Positioning	1S2	W1 0 V	0	0	0		1	0	0	
1	Acceleration to lowering speed	Push button "Lower"	W4 - 10 V	1	1	0	R3 0.05 S/1 V	0	0	1	Lower
2	Deceleration to creep speed II	1B3	W5 - 3 V	0	0	1	R4 0.05 S/1 V	0	0	1	
3	Deceleration to creep speed I	1B2	W6 - 1 V	1	0	1	R4	0	0	1	
4	Positioning	1B1	W1 0 V	0	0	0		0	1	0	Corresponds to the initial position for lifting

Fig. 5/3:
Signal control, electrical

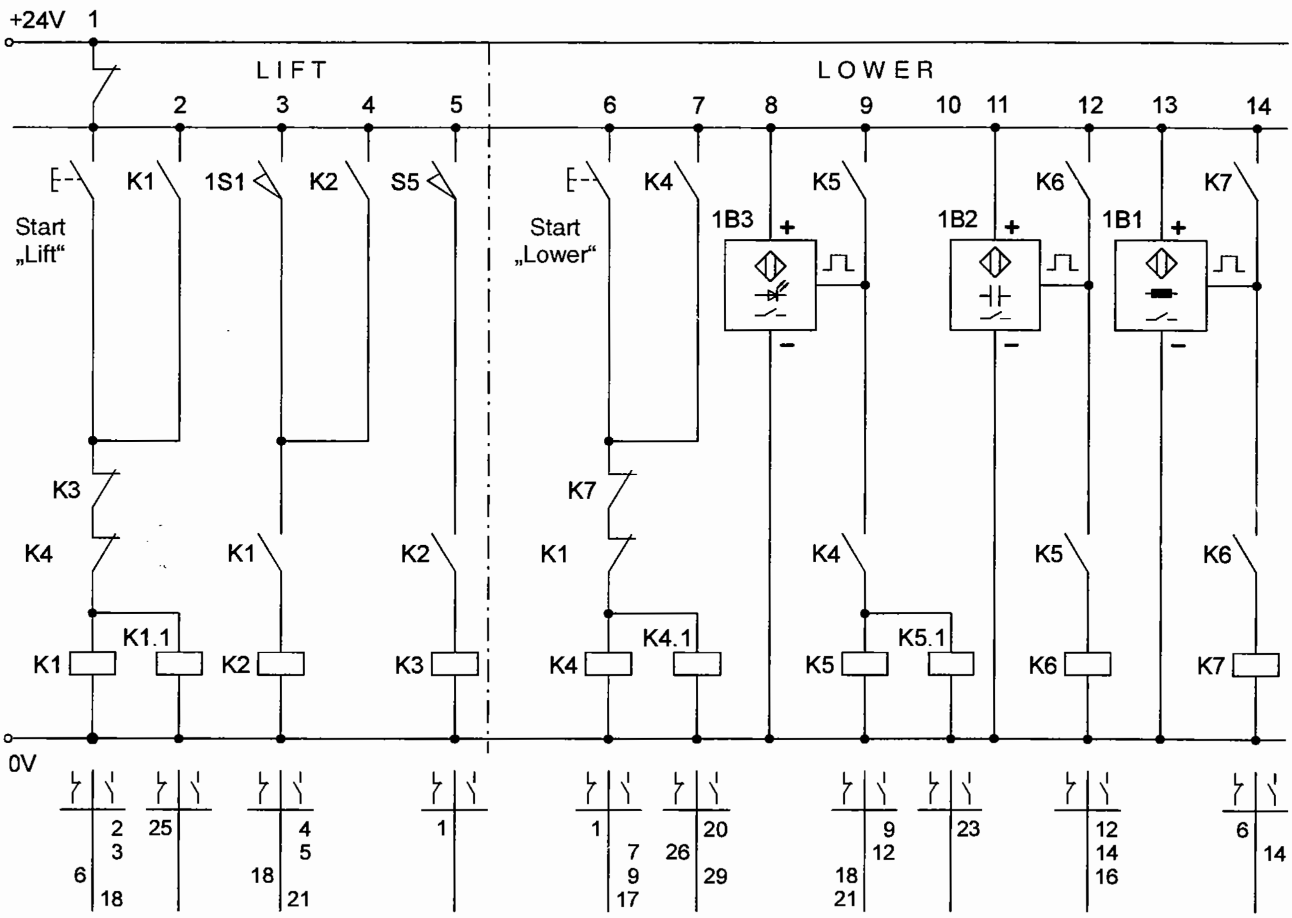
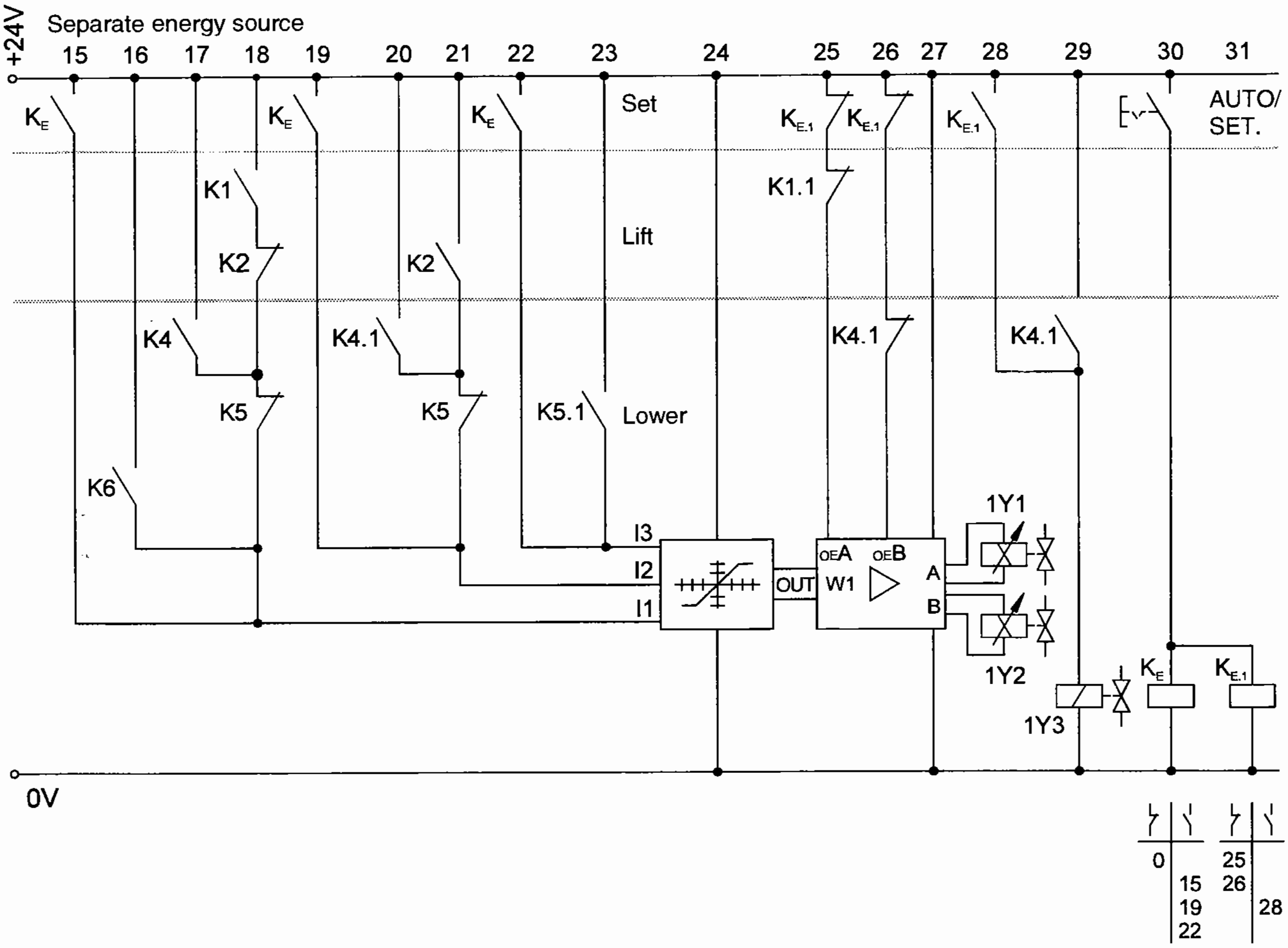


Fig. 5/4:
Signal control, electrical



Solution description

General information regarding interrupt positioning

Interrupt positioning is widely used in hydraulic drive technology. The signal generator approached via rapid traverse/creep speed, emits a signal for the positioning of the drive by means of poppet non-return valves.

A certain time interval is involved from the response time of the signal generator to the completed closing process of the poppet valve and the stopping of the hydraulic drive, which results in the overtravelling of the signal generator.

A favourable solution is a signal control with short, constant switching times, such as that provided by a relay control. In the case of a PLC controller, the cycle time is unfavourable; therefore, an appropriate programming method is used.

The closing process of the piloted poppet valves must be quick, i.e. a 4/3-way proportional valve with mid-position “working lines to tank return” is suitable as a final control element.

The overtravelling distance up to switch-off is to be taken into account when adjusting the signal generator during commissioning.

Our example:

For the practical assembly, the 4/3-way proportional valve with mid-position closed contained in the equipment set is used.

When the position indicator is reached, the amplifier output is switched off and the 4/3-way proportional valve moves directly into the mid-position – the cylinder is in position.

With Festo Didactic control technology, it is possible to close the outputs for the valve control signals to inputs “OA A” and “OA B” by means of a control signal (24 V).

A relay sequencer in the form of a permanent control system for the sequence of rapid traverse/creep speed/position is feasible. The setting of a stage by means of the corresponding signal generator means:

- Output signals for setpoint value polling.
- Preparation of next stage.

All stages remain set up to the last stage. In this exercise, the last stage does not need to remain stored, since it resets the first stage, which in turn resets the next stage until the sequencer has been completely re-set.

With the reaching of a position, the entire sequencer is reset and with the releasing of the first stage, the corresponding amplifier output is switched off. This is the normally closed contact K1.1 in current path 25 for lifting and the normally closed contact K4.1 in current path 26 for lowering. In the respective positions, the setpoint value W1 is selected via the polling code 0/0/0.

W1 is set to 0 volt, thereby permitting acceleration in both directions without initial retardation as soon as “lift” or “lower” is pressed.

Piloted non-return valve and proportional directional control valve

When connecting these two devices together, faultfree opening and closing must be ensured for the specified time period.

Interference of the closing function

Use of a 4/3-way proportional directional control valve with mid-position "closed" does not provide correct relieving for a clean closing of the non-return valve. Moreover, this results in leakage loss towards the two working lines, which are consequently put under pressure – a non-return valve could be opened/activated. In the case of our example, this has been ignored, since this would necessitate additional proportional directional control valves in equipment set TP702.

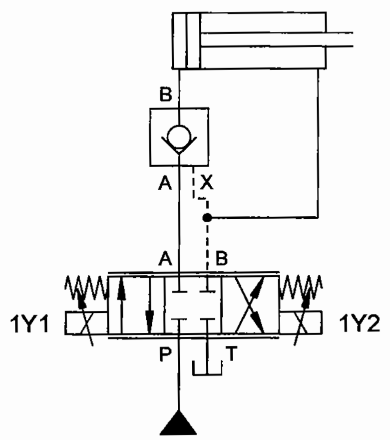


Fig. 5/5:
Actuation using a 4/3-way proportional valve

Interference of activation function

Proportional directional control valves are direction and flow control valves. Flow is controlled in both working lines, whereby pressure is available both between the proportional directional control valve and the cylinder – the activating function may be impeded during the positioning operation.

Remedy:

a) Use of a piloted non-return valve with oil return port.

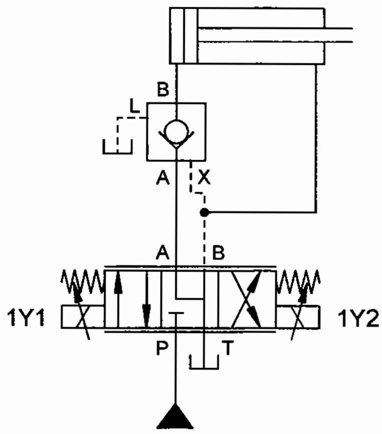


Fig. 5/6:

b) Separate activation by means of a solenoid directional control valve.

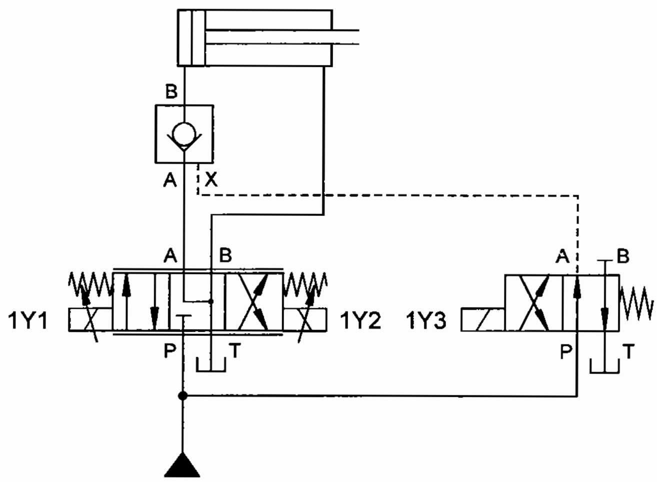


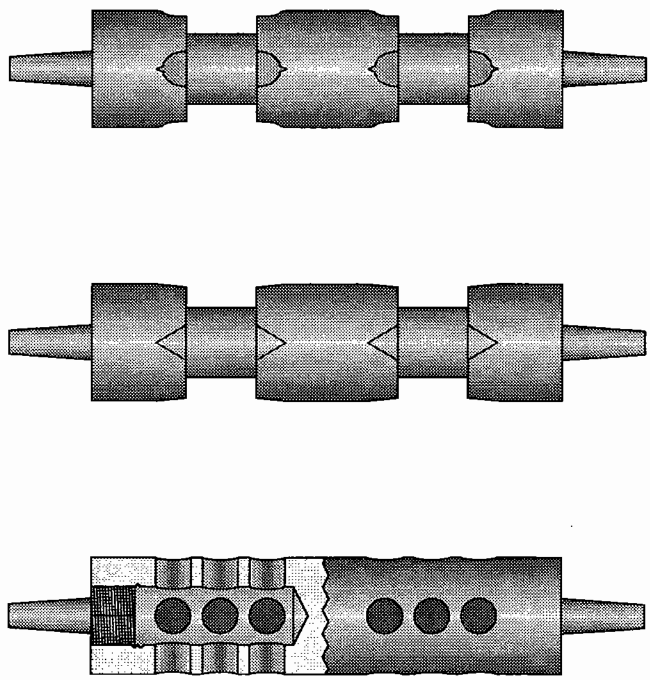
Fig. 5/7:

Control edge geometry

As can be seen from the travel diagram, acceleration and deceleration is irregular. This is due to the progressive characteristic flow curve of the valve. This is created by means of a corresponding control edge geometry of the valve piston. With this, the cross section of the opening is within the control edge geometry.

Below are examples of valve pistons for various drive acceleration patterns.

*Fig. 5/8:
Spool with varying
control edge geometry*



Lowering speed

As a rule, a higher lowering speed is designated in relation to the lifting speed for hydraulic lifts. In this example, deceleration takes place in two creep speed stages, whereby the last stage has a very low value to prevent hard impact on stopping.

Setting operation

For the setting operation, the sequencer is reset in all situations by means of disconnection from supply and manual travel operation, facilitated with setpoint value W8 for setting in both positions. If the setpoint value W8 is at 0 volts, the lift remains stationary.

The setting operation is of advantage if, for instance, the travel command “continue” is given from the upper position. The lift will of course start, but will then be stopped by the cylinder end position. The same also applies for the opposite direction.

As a result of the setting operation and thus the resetting of the sequencer, the latching of the travelling commands “Lift” and “Lower” is also cancelled, whereby a new travel command can be input.

Note for practical assembly on the training unit

In order to also obtain a good representation of positioning optically, we recommend that the signal generators are placed as below.

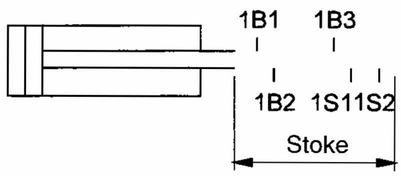


Fig. 5/9: Positional sketch for signal generators

General information regarding hydraulic lifts

The lowering process is effected without a pump, purely by means of the potential energy of the load. The acceleration and deceleration process as well as the lifting and lowering process must be constant and independent of the load. This is why a pressure balance is used for a constant differential pressure over the cross section opening of the valve. See also workbook TP701, exercise 10.

In the case of control technology concepts for lifts, a setpoint value curve is polled for start-up and deceleration and travelled via closed loop control. See also the Festo Didactic training package TP511, Fundamentals of closed-loop hydraulic control.

Safety regulations and parameters

The same applies for the hydraulic lift exercise as with other exercises, i.e. due to the extent of the safety requirements, these have not been fully taken into consideration.

Conclusion

Switching time and stop position

The switching time of the signal control affects the stop position in general. The switching time extends from the response time of the signal generator through to the completed switching process of the hydraulic final control elements. The signal generator is therefore overtravelled by a corresponding distance.

An effective means is a relay control system with short, constant switching times. The switching time is to be taken into account when adjusting the signal generator during commissioning.

Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	2-channel amplifier
IA BASIC	0
IA JUMP	50 mA
IA MAX	800 mA
IB BASIC	0
IB JUMP	50 mA
IB MAX	800 mA
DITHERFREQ	200 Hz

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Pressure filter
1	Double-acting cylinder
1	4/3-way proportional valve
2	Pressure gauge
5	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Proportional amplifier
1	Setpoint value card
1	Switch AUTO/SET
1	Push button “Set”
1	Proximity sensor, optical
1	Proximity sensor, inductive
1	Proximity sensor, capacitive
2	Limit switch
10	Relay, 4-off change-over contacts
1	Time relay, with switch-on delay
1	Set of cables

Drawing press

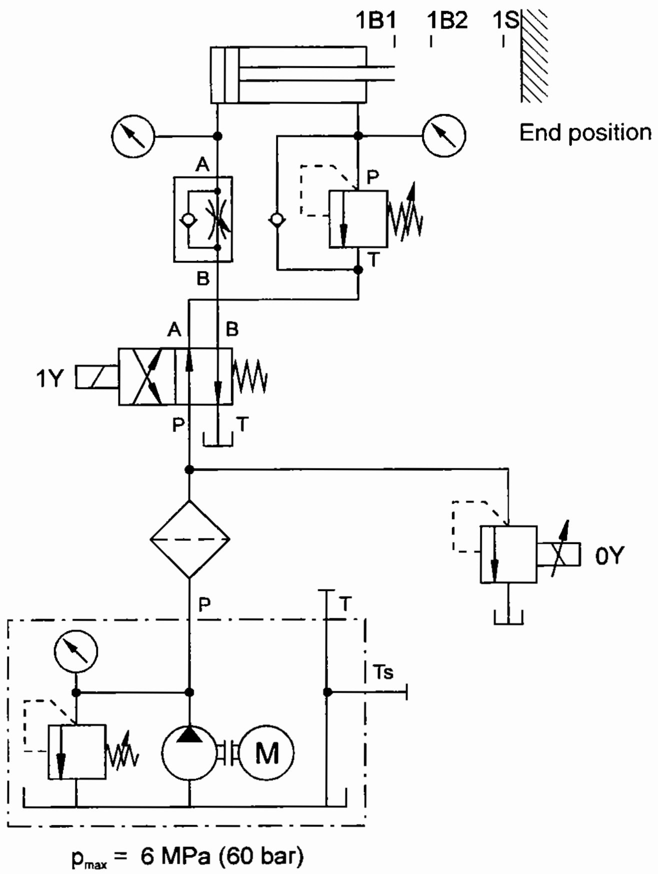
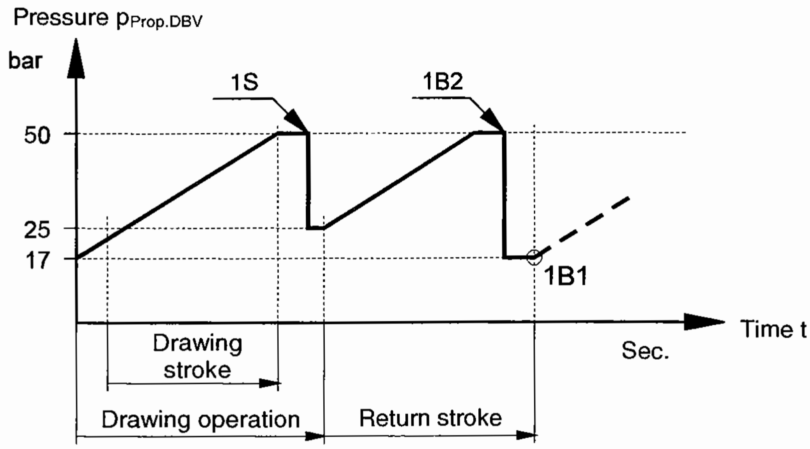


Fig. 6/1:
Circuit diagram, hydraulic

Fig. 6/2:
Signal generator in pressure-time diagram



Sequence table

Step	*Sequence*	*Signal generator*	*Setpoint value* $+ \rightarrow 0Y$	*Setpoint value polling* *I1*	*I2*	*I3*	*Ramp*	*1Y*	*Comment*
1	Acceleration for advancing and drawing action	Start button	W1 10 V ≅ 50 bar	0	0	0	R1 0.05 S /1 V	1	
2	Preparing return stroke – Start Time function	1S	W2 4.5 V ≅ 25 bar	1	0	0	R2 0	1	
3	Acceleration for return stroke	Time expired	W1	0	0	0	R1 active	0	
4	Low pressure stage for smooth retracting	1B2	W3 3 V ≅ 17 bar	0	1	0	R2 0	0	
5	Initial position	1B1	W3	0	1	0		0	

Fig. 6/3:
Signal control, electrical

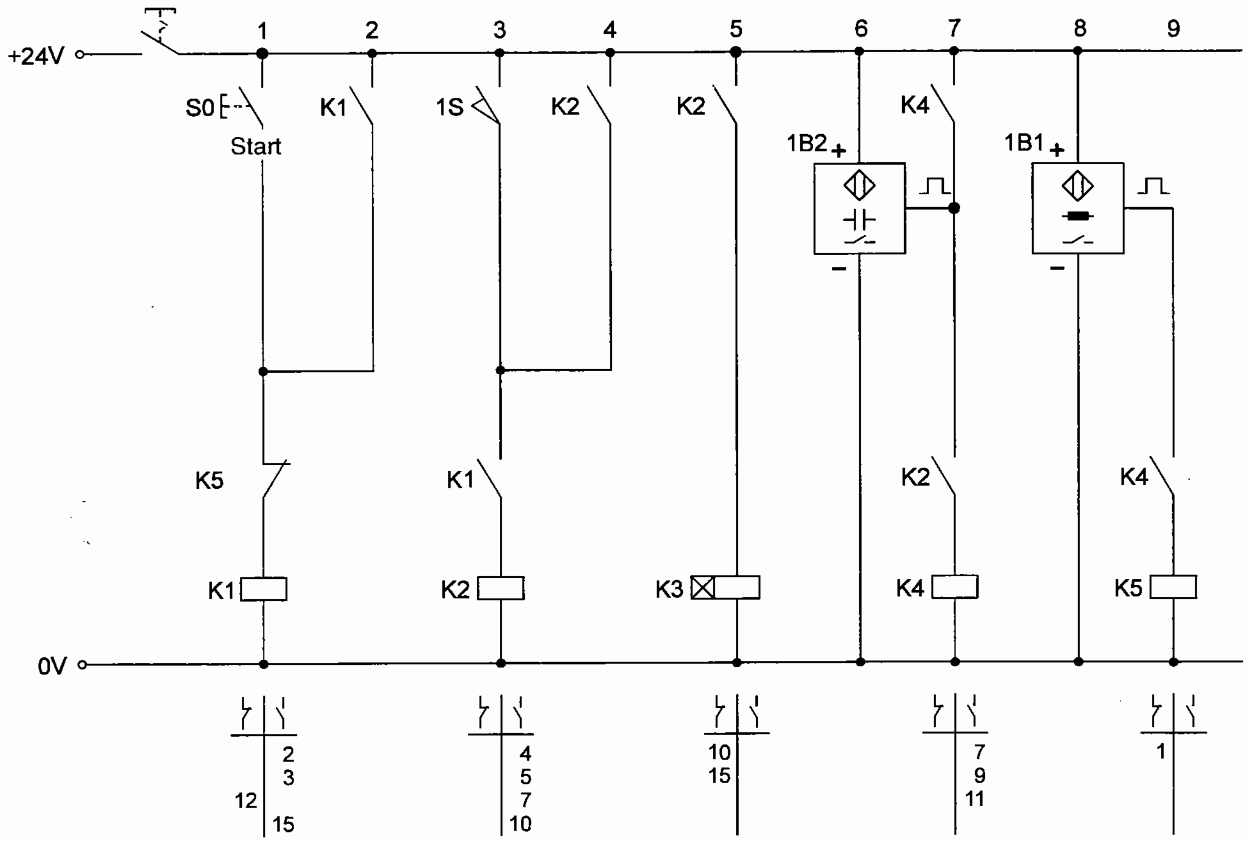
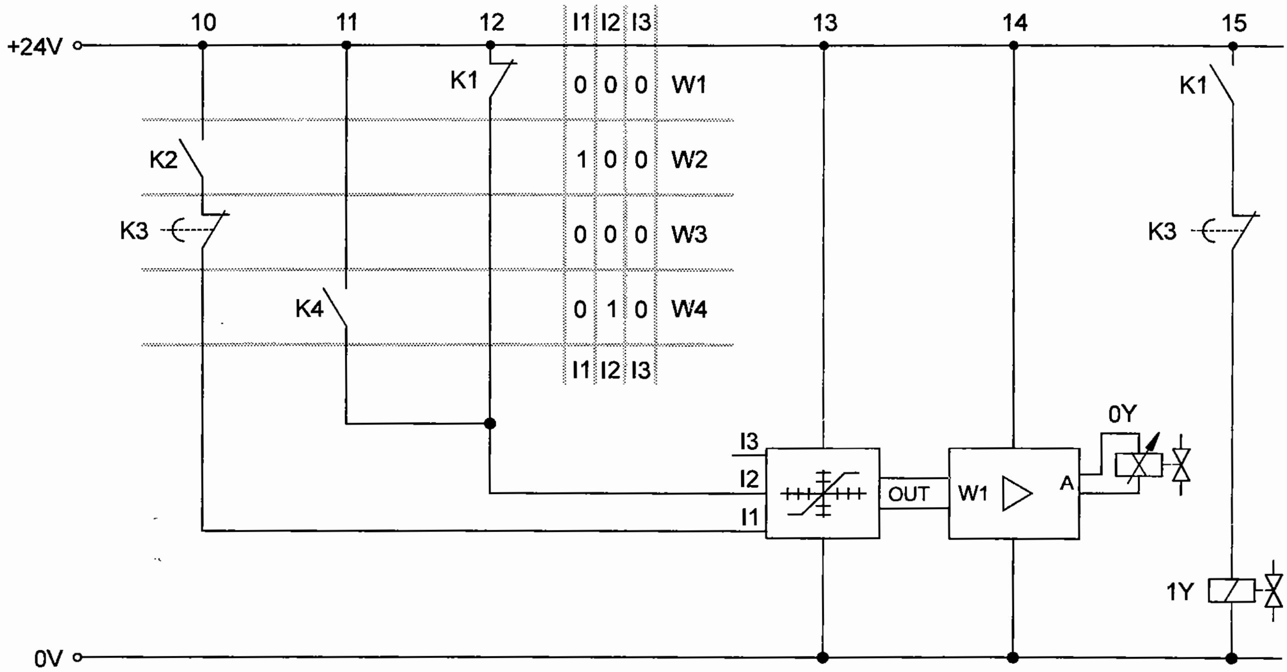


Fig. 6/4:
Signal control, electrical



Solution description

General information regarding acceleration of hydraulic drives

Optimum settings of the starting and decelerating behaviour of a hydraulic drive can be achieved by means of the ramp function of the control electronics.

In some cases, proportional pressure valves may also be used to achieve the acceleration for the drive. However, prior to the acceleration phase, the setpoint value and as such the pressure setting must be reduced and then accelerated by means of the ramp. In the acceleration phase, the proportional pressure relief valve closes continually; the volumetric flow range increases in accordance with the drive.

It is of course not always possible to lower the pressure prior to such a process step, so that this type of solution is the exception rather than the rule.

Regarding this example

A low pressure stage is switched in the initial position by means of setpoint value 3 and the drive maintained in the upper position. After the start, the drawing tool is applied to the sheet metal whilst still at a low pressure and then forms the sheet with increasing force. The setpoint value 1 moves to its value via ramp R1 to its value.

A conventional pressure relief valve is switched as a counter pressure during the entire drawing operation. This is a technical requirement for the starting and overrun distance. In this exercise, the counter pressure simultaneously simulates the forming resistance, whereby the acceleration can also be visibly seen.

Limit switch 1S initiates the return stroke by switching to a low pressure stage in accordance with setpoint value 2 and the counter pressure valve becoming a decelerating valve. Limit switch 1S simultaneously starts a timer, which polls the setpoint value 1 on expiry of 0.1 seconds. The return stroke is accelerated by means of the set ramp R1. A time function is required, since the pressure value needs to be lowered before the acceleration step can be initiated via the ramp. Signal generator 1B2 polls the pressure stage for retraction into the initial position.

A one-way flow control valve has been connected in the exhaust for load simulation. This flow control valve and the counter pressure for the forward stroke are to be set in such a way that the acceleration and deceleration phases are visible.

Conclusion

Prior to the acceleration phase by means of a proportional pressure relief valve, it must be possible to lower the setpoint value and as such the pressure value in the system.

Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	1-channel amplifier
IA BASIC	60 mA
IA JUMP	0 mA
IA MAX	500 mA
IB BASIC	-
IB JUMP	-
IB MAX	-
DITHERFREQ	200 Hz

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Pressure filter
1	Proportional pressure relief valve
1	Double-acting cylinder
1	4/2-way solenoid switching valve
1	Pressure relief valve
1	One-way flow control valve
1	Non-return valve
3	Tee
2	Pressure gauge
9	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Proportional amplifier
1	Setpoint value card
1	Main switch
1	Start push button
1	Proximity sensor, optical
1	Proximity sensor, inductive
1	Proximity sensor, capacitive
1	Limit switch
4	Relay, 4-off change-over contacts
1	Time relay, with switch-on delay
1	Set of cables

Honing machine

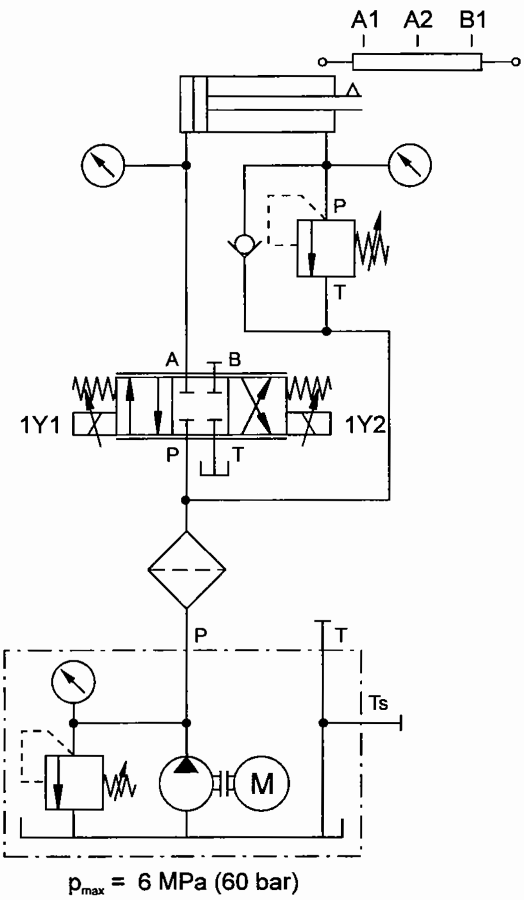
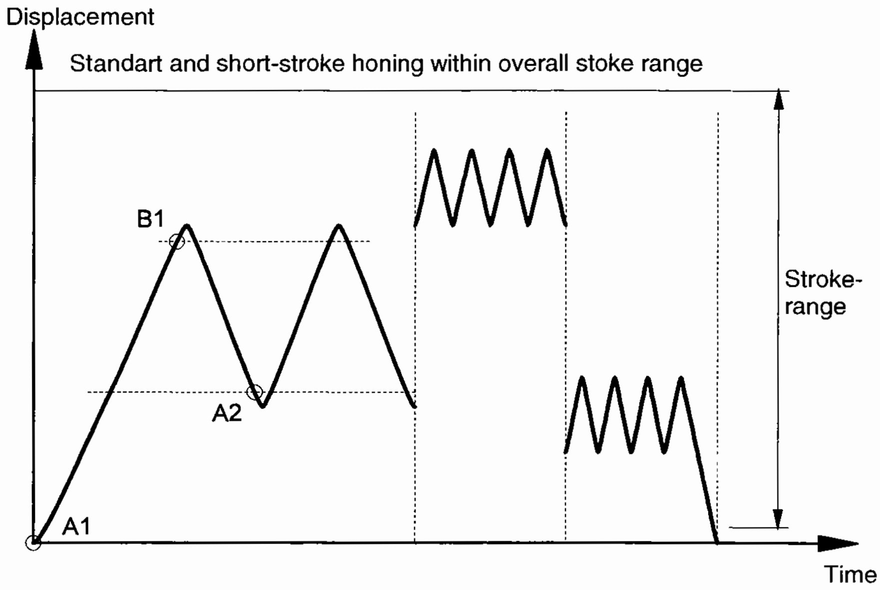


Fig. 7/1:
Circuit diagram, hydraulic

Fig. 7/2:
Signal generator in displacement-time diagram



Sequence table

Step	*Sequence*	*Signal generator*	*Setpoint value* + → 1Y1 - → 1Y2	*Setpoint value polling* I1	I2	I3	*Ramp*	*Comment*
Setting operation	Advancing/ retracting with optional stops	Selector switch AUTO/SET	W8 0 to+ 10 V 0 to- 10 V	1	1	1	Set to "zero"	Reversing in setting operation is possible only in the initial position.
Automatic 1	Approach and honing start	S1 and A1	W2 0 to+ 10 V	1	0	0	R1 0 to 0.05 V/1S	Ramp setting "zero" possible. A1 threshold value infinitely adjustable.
2, 4...	Honing return stroke	B1	W3 0 to- 10 V	0	1	0	R2 0 to R3 0.05 V/1S	Ramp setting "zero" possible. B1 threshold value infinitely adjustable.
3, 5...	Honing forward stroke	A1	W2	1	0	0	R4 0 to R1 0.05 V/1S	Ramp setting "zero" possible. A2 threshold value infinitely adjustable.
n	Continuous operation STOP	S2 without time funct. without incorrect thresh. value	W3	0	1	0	R2 R3	Initiation of return stroke up to initial position..
n+1	Soft stop	A1	W1 0 V	0	0	0	R4	Decelerate to standstill in initial position.
n+2	Initial position	without sensing	W1	0	0	0		Cylinder pressurised in initial position, see hydr. circuit diagram.

Fig. 7/3:
Signal control, electrical

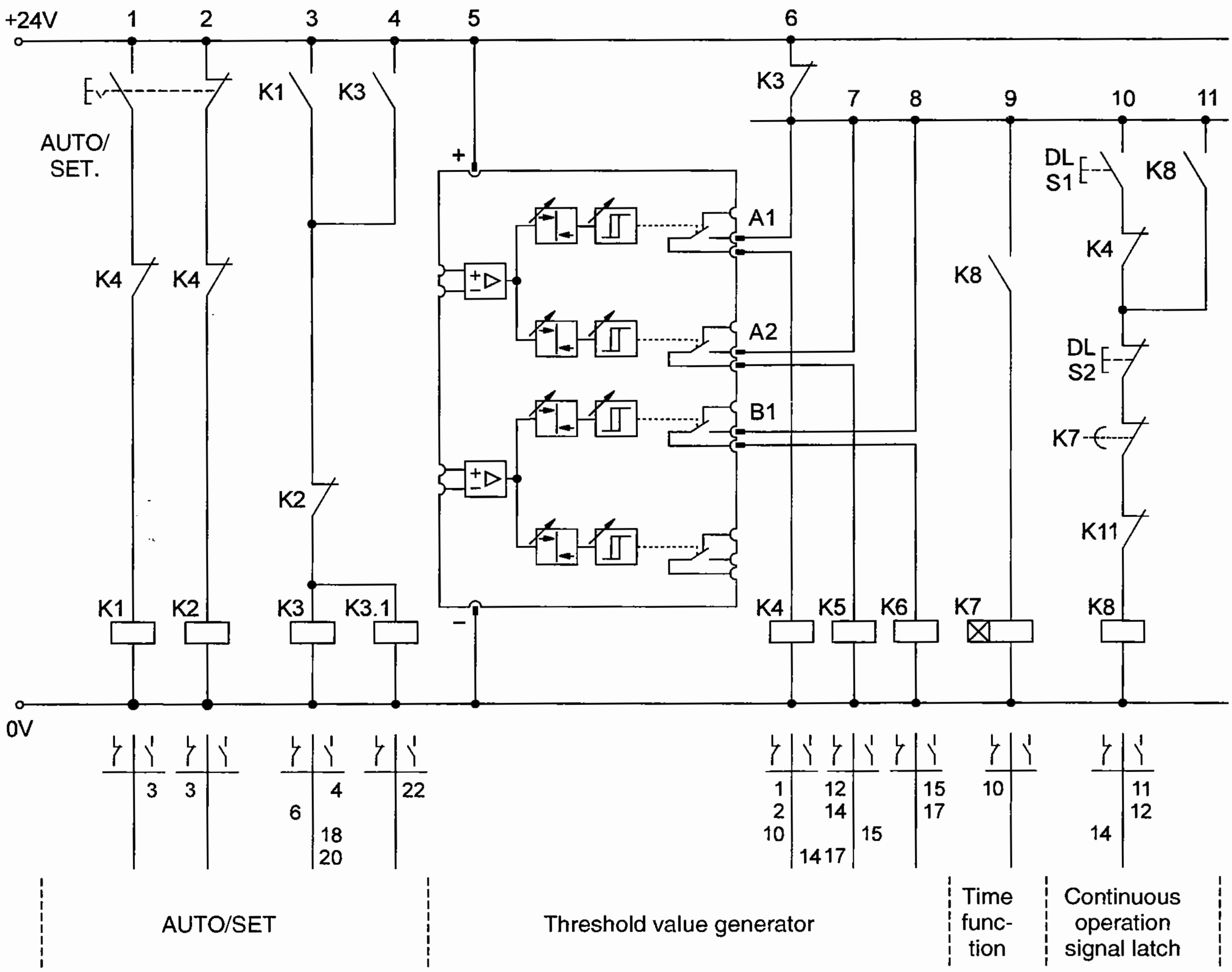
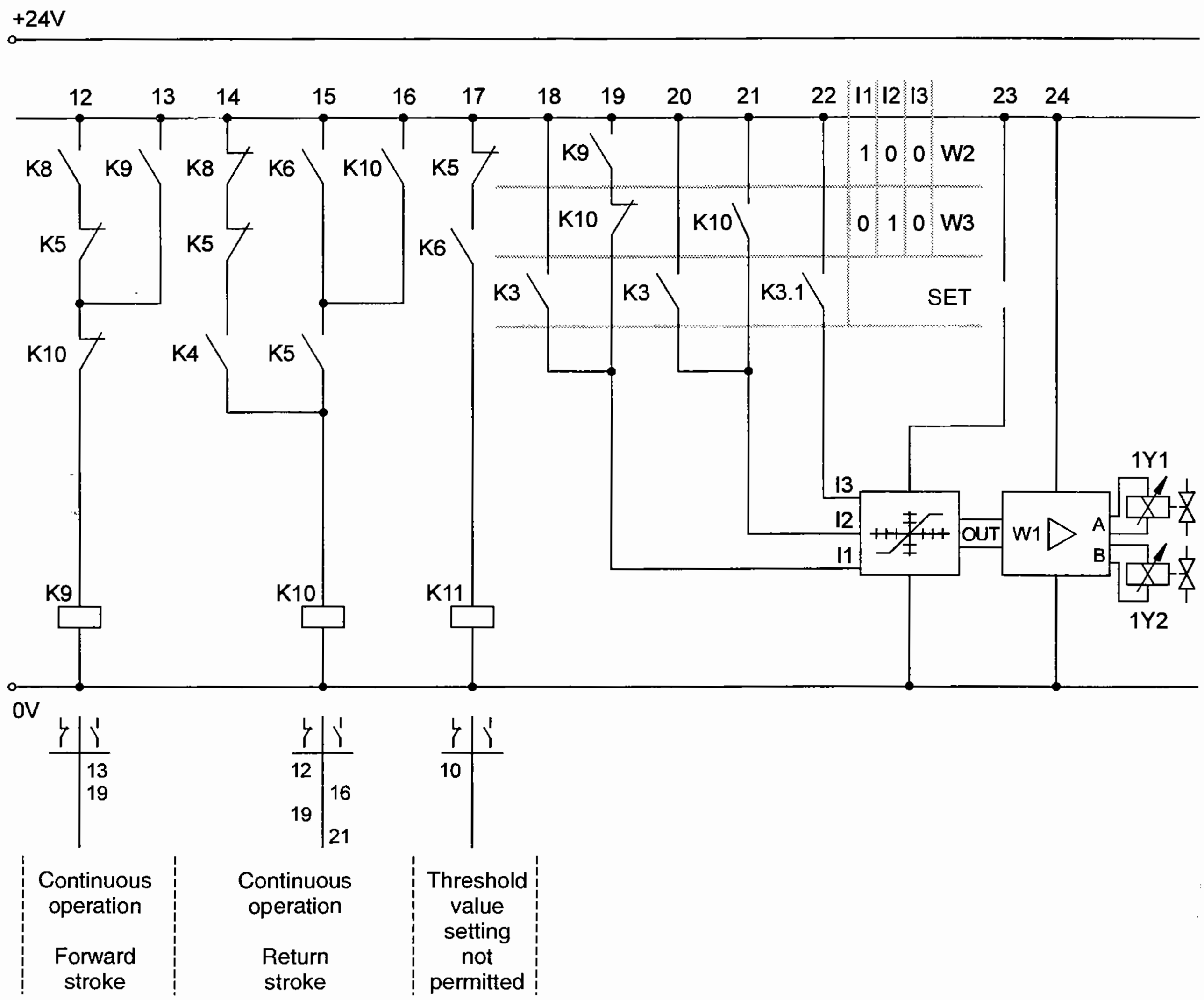


Fig. 7/4:
Signal control, electrical



Solution description

Hydraulic power section

An ideal solution possibility is the bypass circuit using the 4/3-way proportional valve, which is connected in the form of a 3/3-way proportional valve. During the forward stroke, the drive is held by means of the bypass circuit. During the return stroke, optimum holding is effected by means of the flow control action of the proportional valve.

When the hydraulic pump is switched off, a counter-pressure valve based on a poppet principle keeps the drive leakage-oil free in the initial position. The counter pressure can be set low in this exercise.

Signal control

The function and connection of the linear potentiometer and the comparator card has been explained in exercise 3 and is a prerequisite for this exercise. The hysteresis is to be set to "zero", so that all threshold value generators A1, A2 and B1 supply the set setpoint value as threshold value.

As far as the required sequence is concerned, all that is needed is a simple continuous operation between the threshold values A2 and B1, whereby the initial position is to be approached. The initial position is defined by means of the threshold value setting A1. For a position message, A1 must be below the required threshold value.

Current paths 10 and 11 form the signal latching for continuous operation, which is triggered by means of three possibilities: Push button, time function or a non permissible threshold value setting for A2 and B1. If a threshold value B1 is selected in error, which is smaller than A2, then continuous operation will be stopped – current path 17.

With any stop during continuous operation, the cylinder travels across the retracted honing position into the initial position. From the retracted honing point, current path 14 assumes the voltage supply to generate the return stroke signals. As soon as the threshold value for the initial position fails to be met, current path 14 is interrupted by K4. The drive is decelerated to standstill or moves into the end position, depending on the setting of threshold value A1.

Commissioning

During commissioning, it can be seen that without ramp settings a relatively smooth reversing action is achieved, thereby ensuring an efficient honing process.

With ramp settings, the reversing action becomes very smooth which, of course, also results in correspondly longer reversing path. At the point of reversal, the switching of the setpoint value is cancelled via the ramp and, at the same time, the connected setpoint value in the reverse direction is accelerated via the ramp.

The smallest possible stroke can be established in the test:

Threshold values A2 and B1 are brought closer to one another, so that finally, the smallest possible switching time is active between forward and return stroke. The stroke is now determined strictly by the drive speed set.

If the proportional valve with amplifier is adapted to the volumetric flow rate, this results in a high I MAX value, since a high volumetric flow rate is also created during advancing via the bypass circuit. Harmonization can for instance be effected during the oscillating movement by changing I MAX, whilst observing the cylinder speed. The honing speed is reduced with a certain value slightly less than the maximum possible deflection of the control piston. I MAX should be slightly above this.

As a rule, the honing stroke speed setting is the same for both directions. In our solution, various speeds can be set for special cases by means of two setpoint value generators.

Setting operation

The setting operation can be selected in the initial position using the selector switch AUTO/SET. With this, current paths 6 to 17 become de-energised and the setpoint value W8 of the setpoint value card become active.

Precision movement of the drive is possible in both directions.

A reversal to automatic is also only possible in the initial position.

Conclusion

By means of corresponding ramp settings, it is possible to create a smooth reversing action. At the point of reversal, the switched off setpoint value is cancelled via the ramp and at the same time the connected setpoint value in the reverse direction is accelerated via the ramp.

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Pressure filter
1	Double-acting cylinder
1	4/3-way proportional valve
1	Counter-pressure valve (DBV)
1	Non-return valve
3	Tee
2	Pressure gauge
7	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Proportional amplifier
1	Setpoint value card
1	Comparator card
1	Linear potentiometer
2	Push button "Start" and "Stop"
1	Switch "Auto/Set"
11	Relay, 4-off change-over contacts
1	Time relay, with switch-on delay
1	Set of cables

Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	2-channel amplifier
IA BASIC	50 mA
IA JUMP	100 mA
IA MAX	100 mA
IB BASIC	50 mA
IB JUMP	70 mA
IB MAX	100 mA
DITHERFREQ	200 Hz

Mould closing device

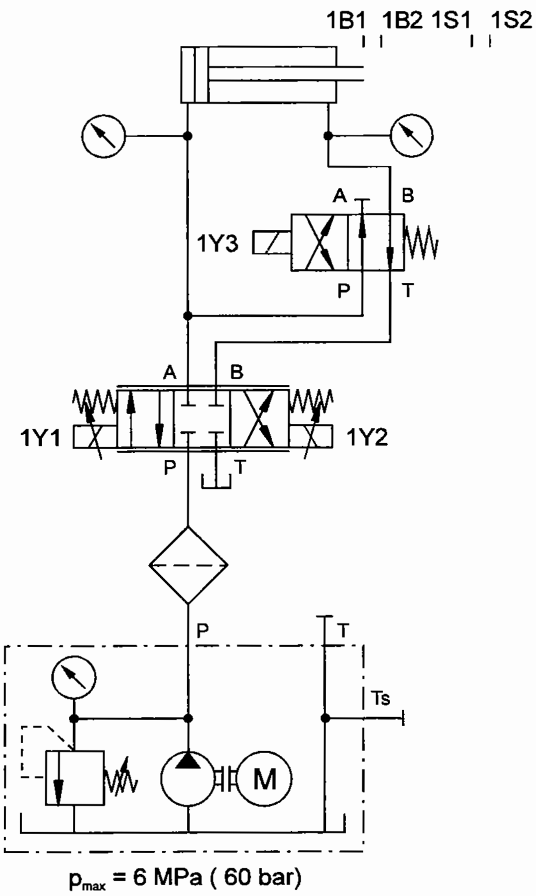
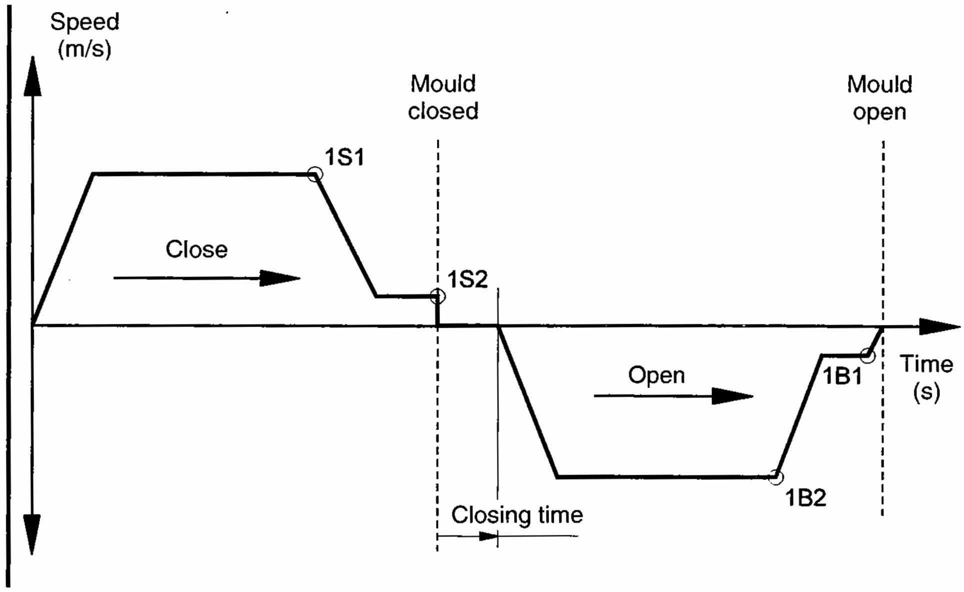


Fig. 8/1:
Circuit diagram, hydraulic

Fig. 8/2:
Signal generator in
V-t-diagram



Sequence table

Step	*Sequence*	*Signal generator*	*Setpoint value* $+ \rightarrow$ *1Y1* $- \rightarrow$ *1Y2*	*Setpoint value polling* *I1*	*I2*	*I3*	*Ramp*	*1Y3*	*Comment*
1	Acceleration to high closing speed	Start button	W2 + 10 V	1	0	0	R1 0 (0.05) V/1S	1	Bypass circuit active
2	Deceleration to closing speed High closing force	1S1	W3 + 3 V	0	1	0	R2 0.05 V/1S	0	Bypass circuit passive - entire piston surface available for force
3	Holding of closed mould	1S2	W3 remains active	0	1	0	-	0	Start of time function for injection moulding process
4	Acceleration to opening speed	Time expired	W4 - 8 V	1	1	0	R3 0.05 V/1S	0	
5	Deceleration to creep speed	1B2	W5 – 2.5 V	0	0	1	R4 0.05 V/1S	0	
6	Deceleration in end position	1B1	W1 – 0.1 V	0	0	0	R4 active		Retracted end position without monitoring
7	Initial position	without sensing	W1 remains active	0	0	0	-	0	

Fig. 8/3:
Signal control, electrical

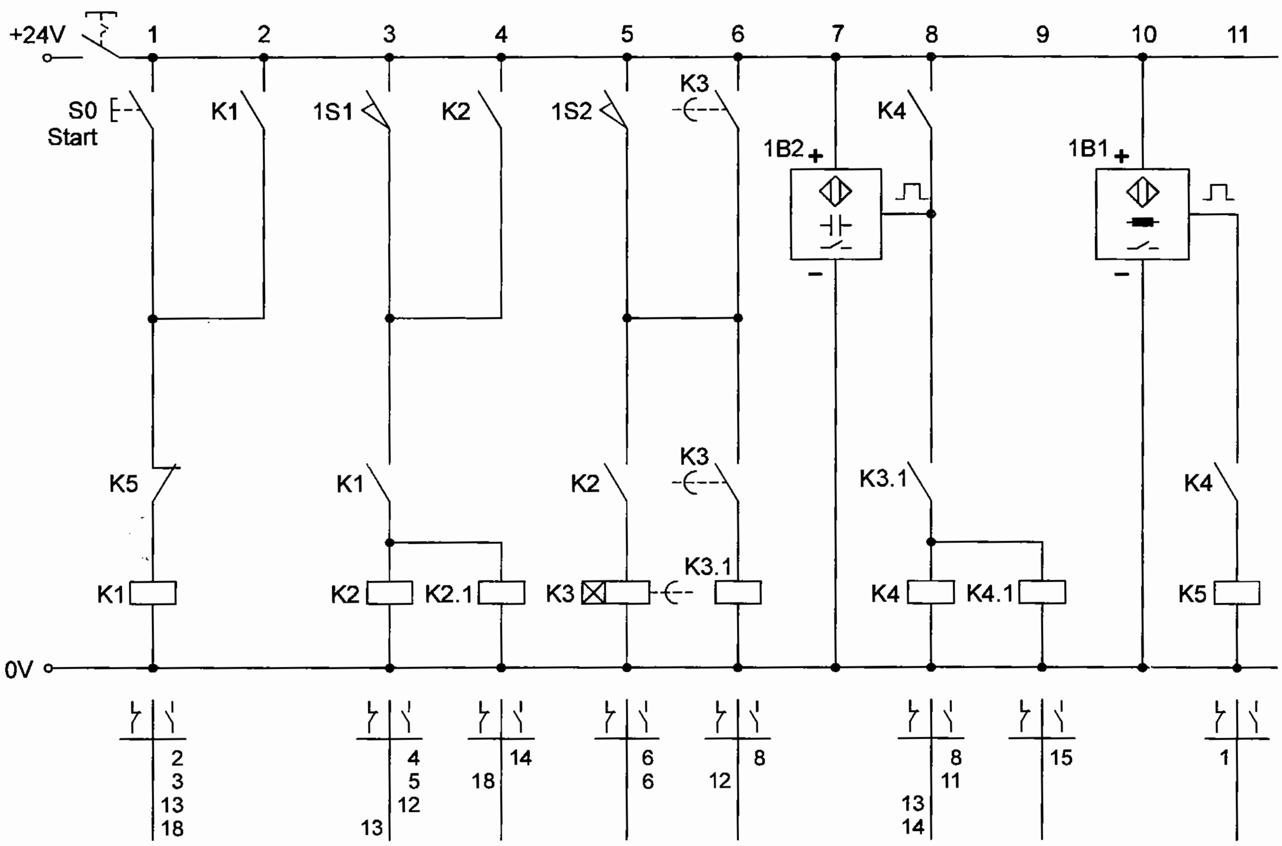
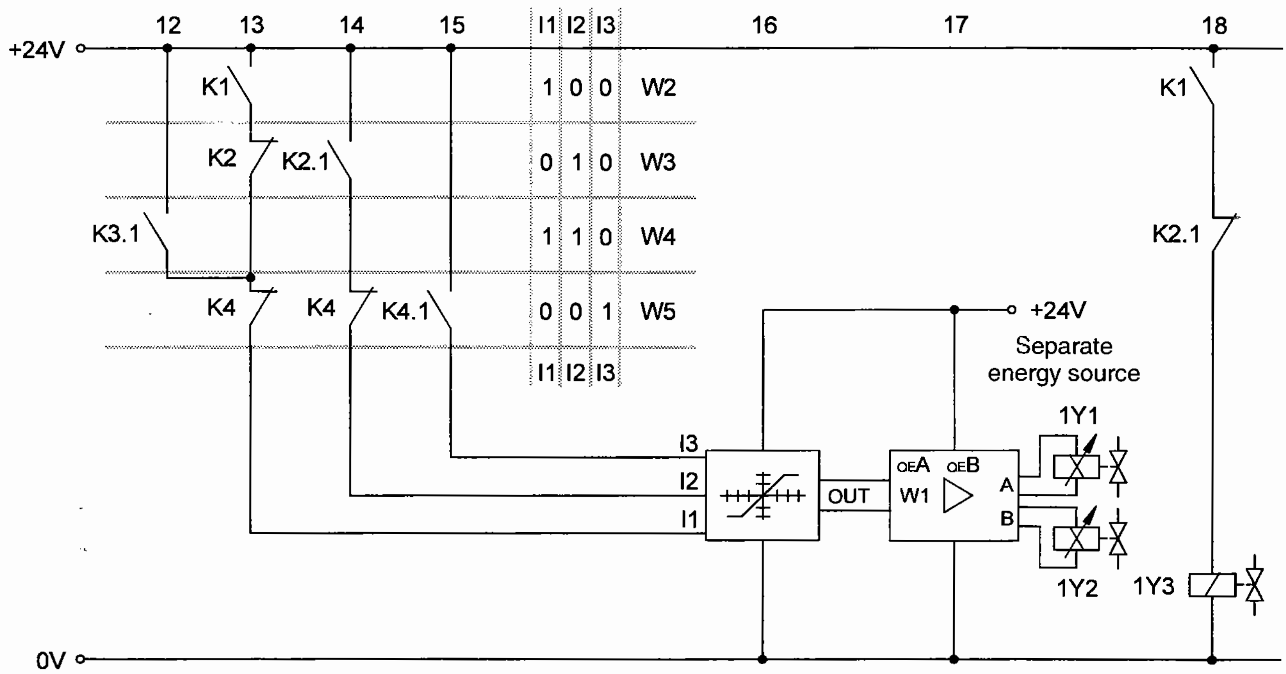


Fig. 8/4:
Signal control, electrical



Solution description

General information regarding bypass circuit

In hydraulic control technology, a bypass circuit for cylinders provides an optimum solution, if increased advancing speeds are required and the dimensions of the cylinder are adequate for the designated force required. Preferably, a cylinder with a surface ratio of 2:1 is to be used. However, the system also functions without any problem with the surface ratio of 1.64:1 of the cylinder contained in this Festo Didactic training package for proportional hydraulics. Naturally, the increase in speed is correspondingly lower and the potential force less.

The bypass circuit for rapid traverse movements is also utilised in proportional hydraulics.

In this example:

The bypass circuit for rapid traverse is achieved by means of a 4/2-way solenoid switching valve, which is connected in the form of a switching gate. The bypass can be switched by means of a 24 V signal.

Initial position by means of soft stop

The initial position must be accurately defined in accordance with the designated solution. In this example, the initial position is reached by switching to a creep speed by means of B B1 via ramp R4. A so-called "soft stop", whose position is not sensed any further.

However, a minimum setpoint value should remain switched (W1= - 0.1 V), in order to achieve the jump function and to prevent an uncontrolled movement at creep speed in the initial position. A correspondingly high basic and jump current for the return stroke side prevents cylinder creep.

It is of course possible to work with a very high basic current on only one side with setpoint value W1= 0 V, in order to keep the cylinder in the retracted end position. However, the behaviour during the approach is less favourable. Try out the above.

Behaviour of controller during start

Setpoint value W2 and the bypass are switched simultaneously via the start signal.

The pre-pressurised volume in the cylinder piston chamber immediately acts on the piston and accelerates this in jumps, since the cylinder is not loaded.

If ramp R1= 0 is set, then the jump does not take place, due to the effect of the volumetric flow from the proportional directional control valves.

Switching over to high closing force

The bypass is cancelled via 1S1 and the entire piston surface thereby released for pressure actuation. At the same time, setpoint value W3 for reduced closing speed is polled via ramp R3.

The mould is held closed using the highest closing force. The injection moulding process is simulated by means of a time function.

Note regarding practical assembly on the training unit

In order to also obtain a good visual representation of the closing and opening process, it is recommended that the placing of the signal generator as specified below , be roughly maintained.

Assembly, commissioning and harmonization is to be effected in the same way as described in exercise 1.

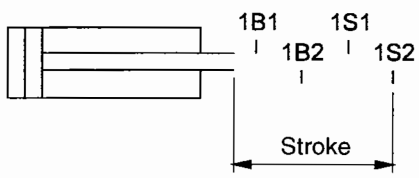


Fig. 8/5: Positional sketch for signal generators

Conclusion

As a result of the bypass, a large volumetric flow is available for the rapid traverse movement. By switching off the bypass, the entire piston surface can be pressurised for a high closing force.

Proportional hydraulics also make use of the advantages of this connection technology.

Solution 8

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Pressure filter
1	Double-acting cylinder
1	4/3-way proportional valve
1	4/2-way solenoid switching valve
1	Tee
2	Pressure gauge
7	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Proportional amplifier
1	Setpoint value card
1	Main switch
1	Push button “Start”
1	Proximity sensor, inductive
1	Proximity sensor, capacitive
2	Limit switch
7	Relay, 4-off change-over contacts
1	Time relay, with switch-on delay
1	Set of cables

Harmonization of Amplifier card

Selector switch	*Display*
FUNCTION	2-channel amplifier
IA BASIC	0
IA JUMP	50 mA
IA MAX	800 mA
IB BASIC	80 mA
IB JUMP	100 mA
IB MAX	700 mA
DITHERFREQ	200 Hz

Injection moulding machine

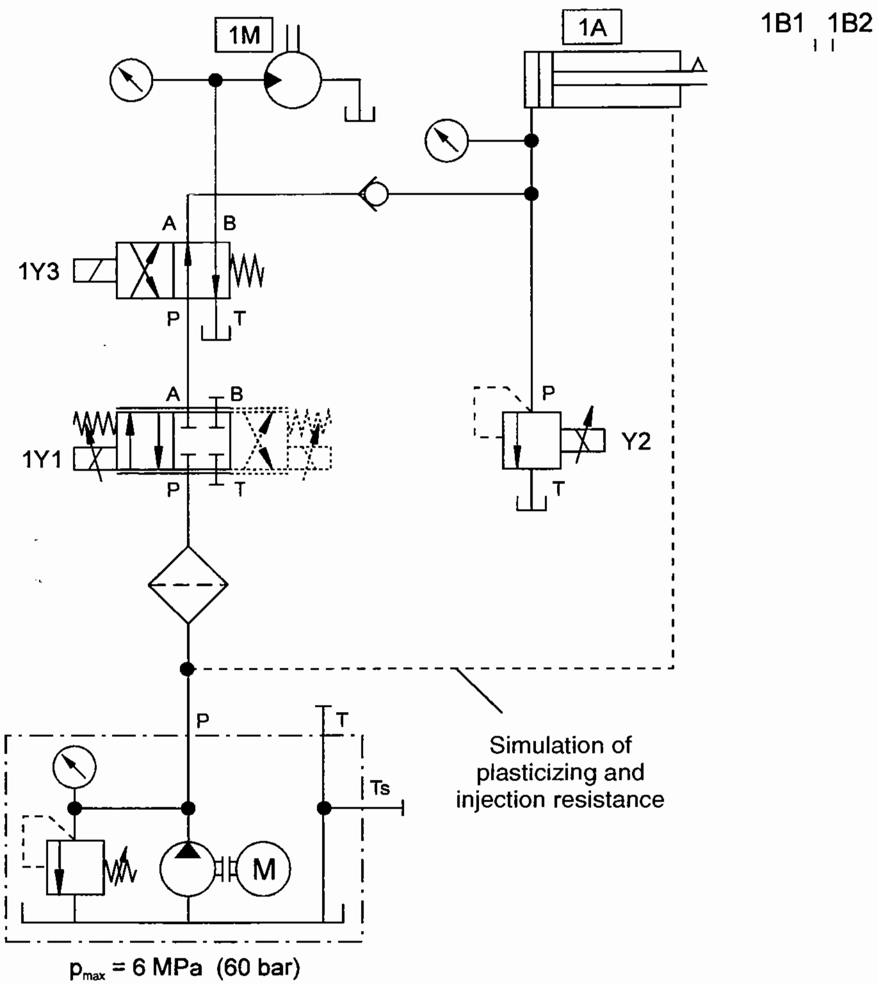
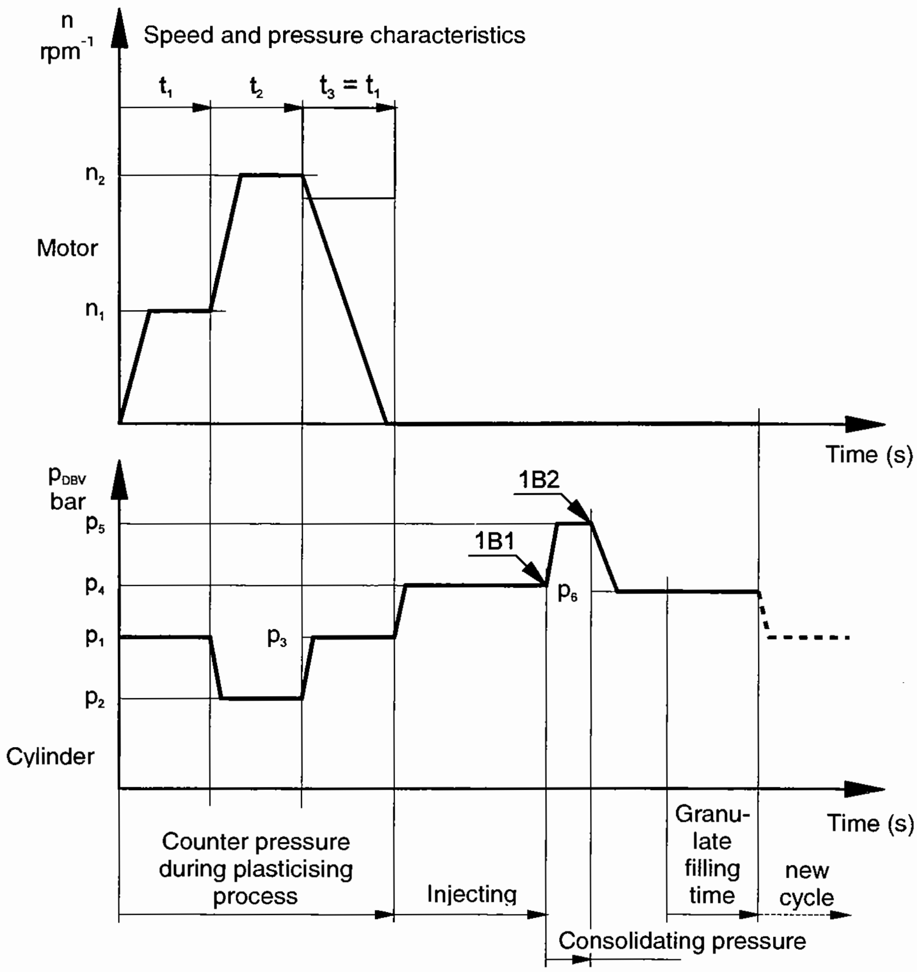


Fig. 9/1:
Circuit diagram, hydraulic

Fig. 9/2:
Signal generator in diagram



Proportional-Flow control valve

Sequence table

Time and process oriented sequence		*Setpoint value*	*Setpoint value polling*					
Step-No.	*Sequence*	*1Y1*	*I1*	*I2*	*I3*	*Ramp*	*1Y3*	*Comment*
1	Accel. motor to n1	W2 3.5 V	1	0	0	R1 0.05 V/1S	1	Start button S1
2	Accel. motor to n2	W3 7.5 V	0	1	0	R1	1	Clock pulse K7 3 - 4 sec.
3	Decelerate motor to standstill	W4 0V	1	1	0	R2 0.80 V/1s	1	Clock pulse K8 5 - 6 sec.
4	Accel. inj. cylinder to V1	W5 4.5 V	0	0	1	R1	0	Clock pulse K7
5	Accel. inj. cylinder to V2	W6 10 V	1	0	1	R1	0	B1
6 Initial pos.	Cylinder advanced	W1 3.0 V	0	0	0		0	B2

Proportional- Pressure relief valve

Sequence table

Time and process oriented sequence		*Setpoint value*	*Setpoint value polling*					
Step-No.	*Sequence*	*1Y1*	*I1*	*I2*	*I3*	*Ramp*	*1Y3*	*Comment*
1	Counter pressure 32 bar	W2 5.2 V	1	0	0	R2 0.05 V/1S	1	Start button S1
2	Counter pressure 20 bar	W3 3.9 V	0	1	0	R2	1	Clock pulse K7 3 - 4 sec.
3	Counter pressure 30 bar	W4 4.8 V	1	1	0	R1 0.05 V/1S	1	Clock pulse K8 5 - 6 sec.
4	Injecting pressure to 45 bar	W5 8.5 V	0	0	1	R1	0	Clock pulse K7
5	Injecting pressure to 57 bar	W6 9.0 V	1	0	1	R1	0	B1
6 Initial pos.	Counter pressure 40 bar	W1 6.2 V	0	0	0		0	B2

Note

The steps 1-6 for the proportional flow control valve and the proportional pressure relieve valve are executed parallel. Please refer to signal branching on page C-79.

Fig. 9/3:
Signal control, electrical

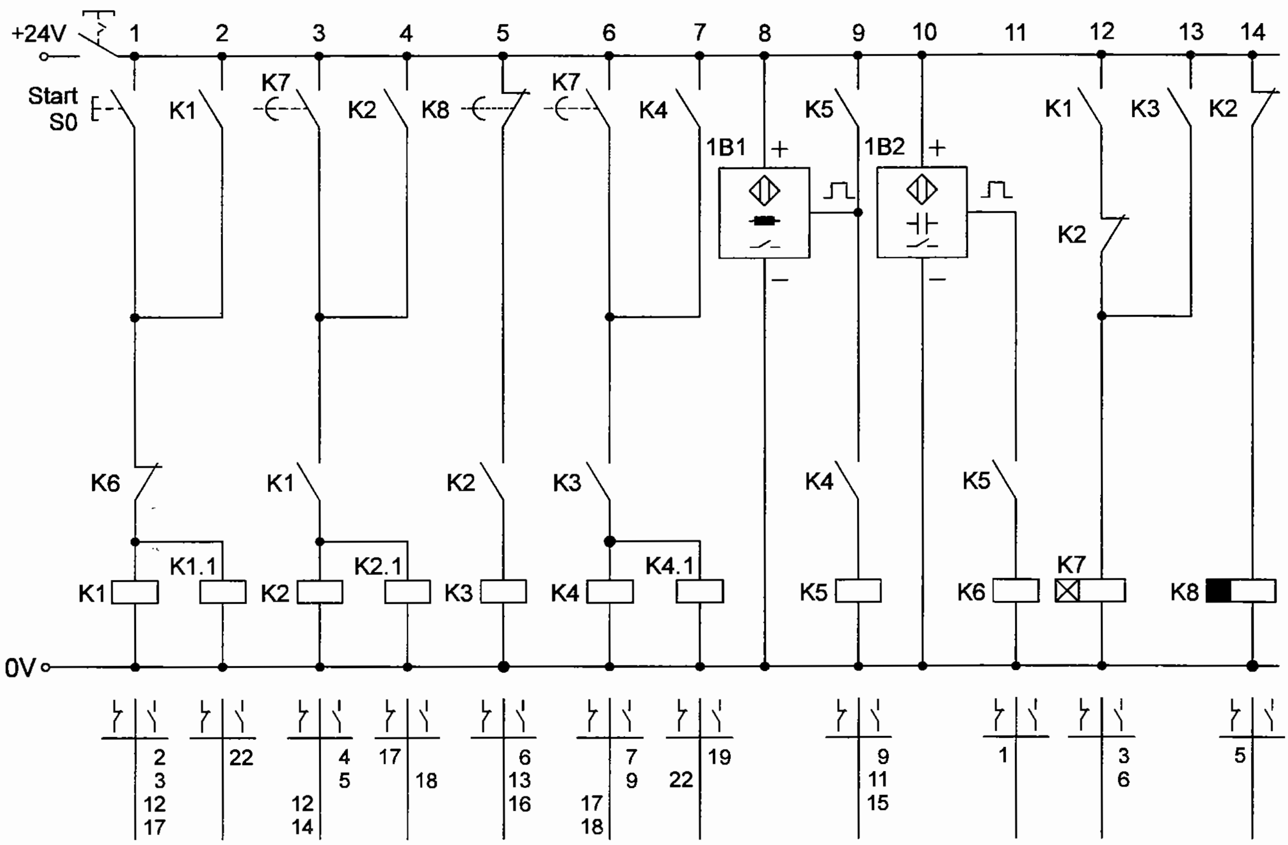
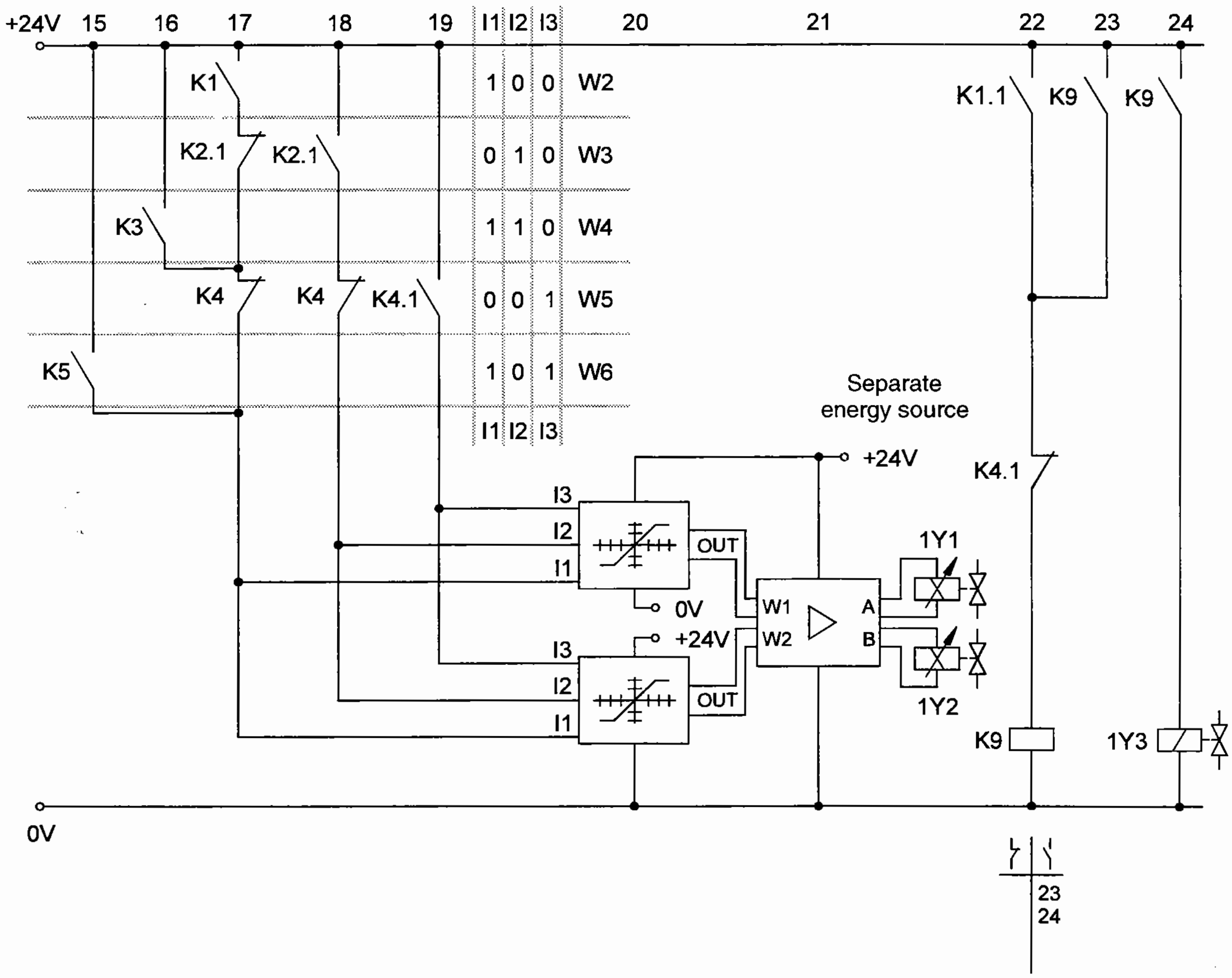


Fig. 9/4:
Signal control, electrical



Solution description

General information regarding speed control systems of several hydraulic drives using a proportional flow control valve

If a speed control systems is required for just one hydraulic drive within an individual process step, then the entire speed control can be assumed by a single proportional flow control valve. Fewer control units mean reduced investment expenditure and generally also a reduction in repair costs.

Regarding this example:

The above described speed control system can be used for the designated injection moulding process. For this, the 4/3-way proportional valve is connected in the form of a 2/2-way proportional flow control valve.

The plasticising and injection moulding process is time controlled, the consolidating pressure is stroke-dependent.

As can be seen from the sequence table, the same setpoint value allocation is made for the two setpoint value cards in the individual process step. This minimises the electrical signal control. The setpoint value inputs are simply switched in parallel.

Throughout the entire process, the plasticising and injection resistance is simulated onto the cylinder annular surface by means of the pump output pressure, whereby the injection moulding process can be very realistically demonstrated.

The counter pressures for the injecting cylinders must be set in such a way that the cylinder is pushed back during the plasticising process, reaching the retracted end position roughly when the motor comes to rest. This can be further optimised by means of an individual clock-pulse setting, whereby clock-pulses 1 and 3 are identical. The injection moulding starts on expiry of the third clock pulse. The consolidating pressure is applied via a position indicator.

The clock pulses are roughly within a range of 3 to 6 seconds.

As can be seen from the sequence table, switching takes place from setpoint value 6 to setpoint value 1 for the proportional flow control valve at the end of the cycle. With this, the setpoint value operates via ramp R2 from 10 volts to 3 volts. A restart should therefore not take place before the ramp time has expired, since a high speed value n1 could be immediately implemented. In practice, this would of course be the filling time for the granular material.

Conclusion

If a high speed control is required for just one hydraulic drive within an individual process step, then the entire speed control for all drives can be assured by an individual proportional flow control valve.

Harmonization of Amplifier card

Valve	*Selector switch*	*Display*
	FUNCTION	2-channel amplifier
Proportional flow control valve	IA BASIC	50 mA
	IA JUMP	80 mA
	IA MAX	800 mA
Proportional pressure relief valve	IB BASIC	50 mA
	IB JUMP	0
	IB MAX	750 mA
	DITHERFREQ	250 Hz

Components list, hydraulic

Item	*Description*
1	Hydraulic power pack
1	Pressure filter
1	Double-acting cylinder
1	Hydromotor
1	4/3-way proportional valve in the form of 2/2-way proportional flow control valve
1	Proportional pressure relief valve
1	4/2-way solenoid switching valve
1	Non-return valve
2	Tee
3	Pressure gauge
10	Hose

Components list, electrical

Item	*Description*
1	Power supply unit
1	Proportional amplifier
1	Setpoint value card
1	Main switch
1	Push button “Start”
1	Proximity sensor, inductive
1	Proximity sensor, capacitive
10	Relay, 4-off change-over contacts
1	Time relay, with switch-on delay
1	Time relay, with switch-off delay
1	Set of cables

Injection moulding machine with mould closing device

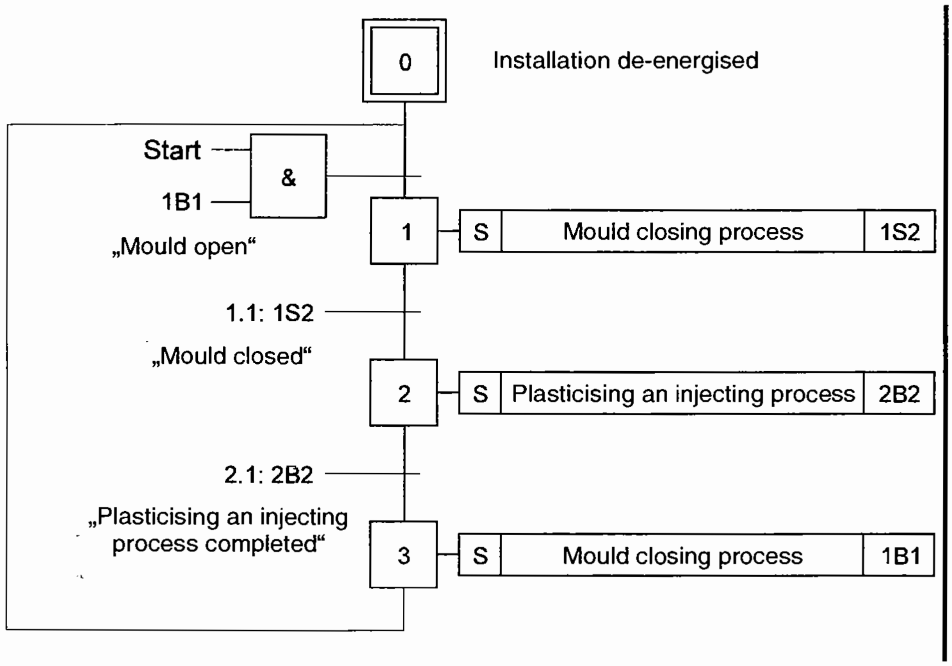


Fig. 10/1:
Function chart

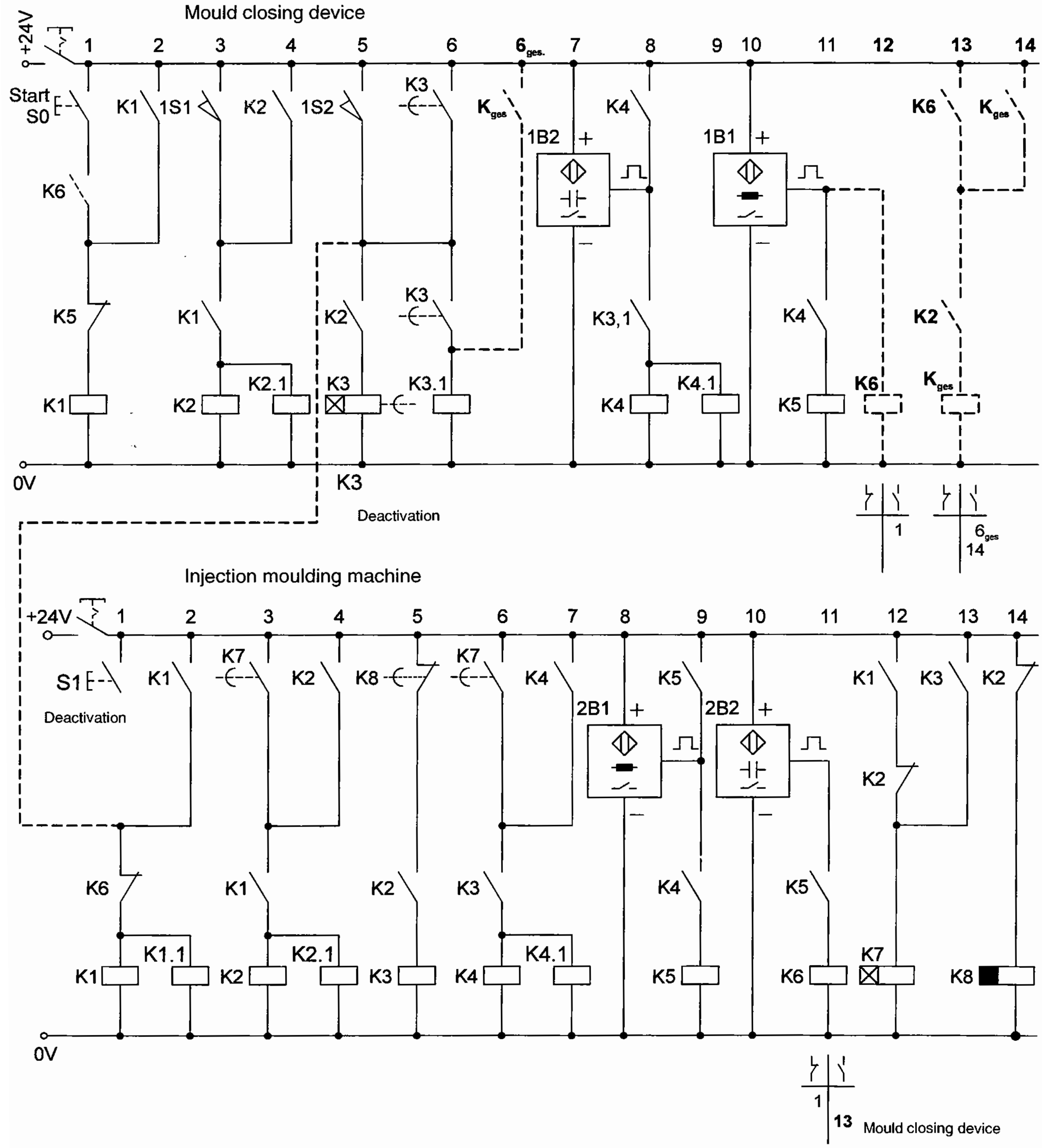


Fig. 10/2:
Signal control system,
electrical

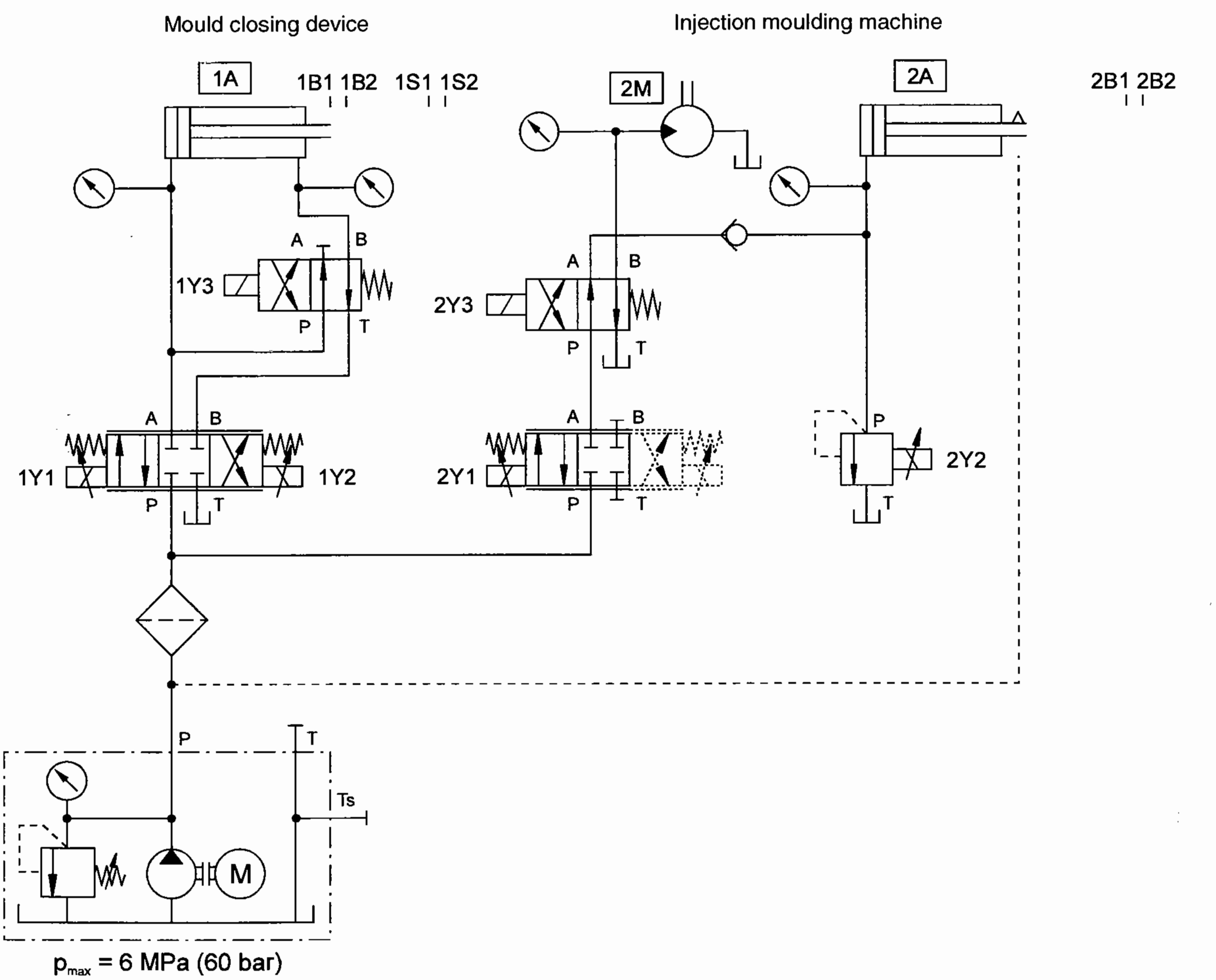


Fig. 10/3:
Circuit diagram, hydraulic
Injection moulding machine
– overall installation

Solution description

Objective

Two separate projects are to be combined into one, although this may still comprise two separate hydraulic training workstations.

For instance, the exercises “mould closing device” and “injection moulding machine” are to be designed, constructed and commissioned individually on the training workstations 1 and 2 respectively.

The individual systems can then be linked together into one overall system to include all groups.

Apart from the extended group work, it is also possible to represent a relatively more complex overall process.

The necessary signal interface is simple and can be easily implemented in the form of a modification or adaptation.

Overall project from the outset

From the outset, this same exercise can also be carried out as an overall project. A complete hydraulic circuit diagram is contained in this exercise for this purpose.

No overall electrical circuit diagram has been drawn up as a solution since, ideally, individual electrical circuit diagrams of the mould closing unit and injection moulding machine are to be used. This results in a systematic and reliable assembly and permits the testing and commissioning of the individual processes.

Only then is the interface logic operation to be integrated. This subsequent logic operation of two individual processes is one of the training aims formulated in this exercise. The interface logic operation is drawn by a dashed line in the electrical circuit diagram.

The function chart as specified in DIN 40719 / 6 (IEC 848)

The function chart is a process-oriented representation of a control task, irrespective of the technical realisation.

A function chart facilitates the precise recording and description of a control task.

Conclusion

As can be seen from exercise 10, it is an advantage to first of all structure and represent the required overall process irrespective of technology.

Generally, and in particular in the case of proportional hydraulic problem descriptions, this can be easily solved by means of a function diagram.

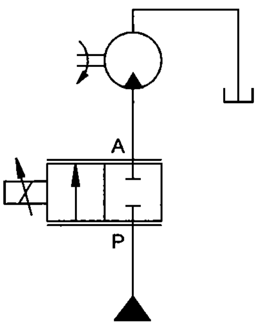
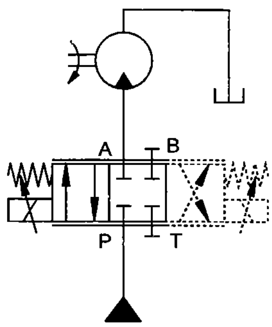
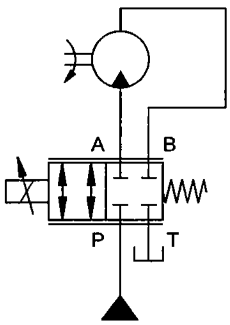
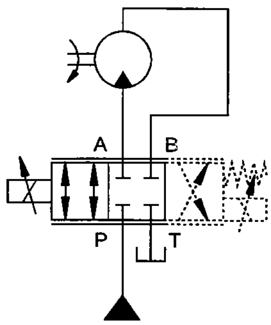
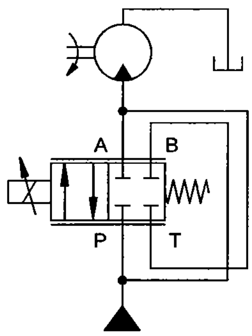
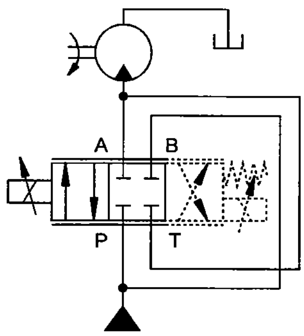
Components list, hydraulic overall installation

Item	*Description*
1	Hydraulic power pack
1	Pressure filter
2	Double-acting cylinder
1	Hydraulic motor
2	4/3-way proportional valve
1	Proportional pressure relief valve
2	4/2-way solenoid switching valve
1	Non-return valve
4	Tee
4	Pressure gauge
16	Hose

Components list, electrical overall installation

Item	*Description*
1	Power supply unit
2	Proportional amplifier
3	Setpoint value card
2	Main switch (latching switch)
1	Push button “Start”
2	Proximity sensor, inductive
2	Proximity sensor, capacitive
2	Limit switch
19	Relay, 4-off change-over contacts
2	Time relay, with switch-on delay
1	Time relay, with switch-off delay
2	Set of cables

Equivalent circuits

Circuit diagram with 2/2-way proportional valve and 4/2-way proportional valve	*Description*	*Circuit diagram with 4/3-way proportional valve*
	2/2-way proportional valve connected into the supply flow. No counter pressure exists.	
	4/2-way proportional valve connected into the supply flow. Counter pressure exists as result of adjusted flow control apperture ratio. P → A : B → T = 1 : 1	
	4/2-way proportional valve connected into the supply flow with double flow rate. both cross sections of flow P → A and B → T are utilised for in-creased flow rate. Without counter pres-sure.	

Section D – Appendix

Data sheets

Mounting systems

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

There is a choice of four alternative systems for mounting the components on the profile plate:

Variant A: Detent system, used without additional devices,
Clamping mechanism with lever and spring,
which can be moved along the T-groove,
for light non-load bearing components.

Variant B: Rotary system, used without additional devices,
Grip nut with locking disk and T-head bolt,
vertical or horizontal alignment,
for medium-weight load-bearing components.

Variant C: Screw-in system, used with additional devices,
Cheese-head bolt with T-nut,
vertical and horizontal alignment,
for heavy load-bearing components or components
which are rarely removed from the profile plate.

Variant D: Plug-in system, used with adapter,
components used on plug-in assembly board
with locating pins, can be moved along the T-groove,
for light, non-load-bearing components.

The signal input unit and indicator and relay plate can also be assembled in the mounting frame for ER units.

In the case of **variant A**, a slide engages in the T-groove of the profile plate. This slide is pre-tensioned by a spring. When the blue lever is pressed, the slide is retracted to allow the component to be removed from or fitted to the profile plate. Components are aligned with the groove and can be moved along this.

In the case of **variant B**, the component is secured to the profile plate by a T-head bolt and a blue grip nut. A locking disc which can be positioned in steps of 90° is used to position the components, allowing these to be aligned either parallel to or at right angles to the grooves.

After the locking disc has been set to the desired position, the component is placed on the profile plate. When the grip nut is turned clockwise, the T-head bolt is turned through 90°in the T-groove by thread friction. The grip nut is then turned further to clamp the component to the profile plate.

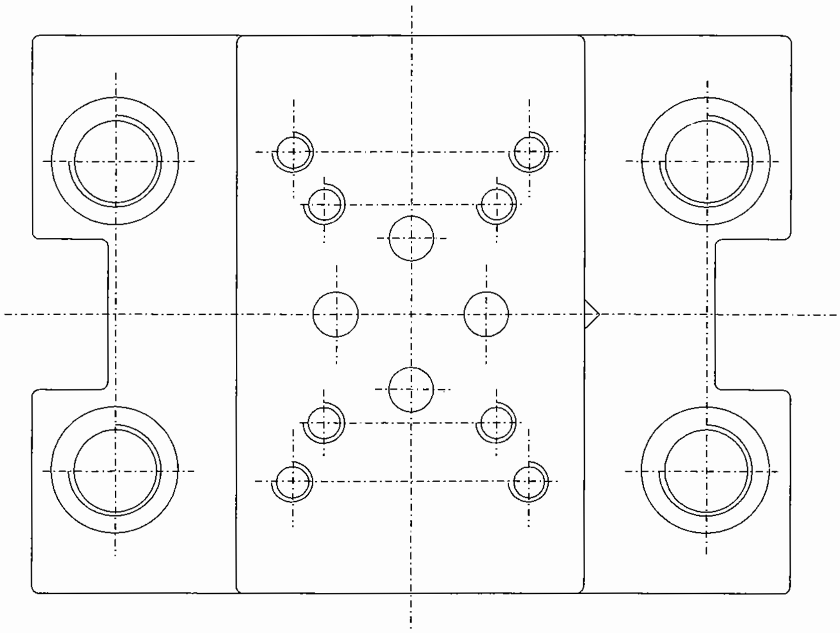
Variant C is used with heavy components or components which are to be secured to the profile plate once only or seldom removed. In this case, components are secured by means of internal-hex-head bolts and T-head nuts.

In the case of **variant D**, our well-proven ER units, for plug-in assembly boards with locating pins on a 50 mm grid pattern, can be attached to the profile plate by means of adapters. A black plastic adapter is required for each locating pin. The adapters are positioned in the T-grooves at intervals of 50 mm and secured by rotating them through 90°. The locating pins of the ER units are then inserted into the holes in the adapters.

Sub-base

The hole pattern of the sub-base for valves of nominal size 4 (DN 4) conforms to ISO 228 size 02. Due to the similarity between this hole pattern and the one for size 03, it has been possible by changing the dimensions slightly and providing additional mounting holes to allow valves of nominal size 6 (DN 6) to be used as well.

Connection panel

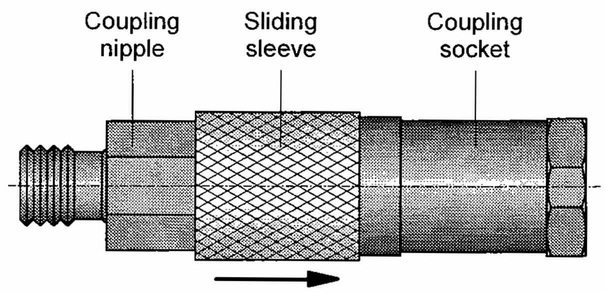


Coupling system

All hydraulic components are equipped with self-closing couplings. These have been designed in particular enabling circuits to be assembled and dismantled with nearly no oil leakage, while at the same time allowing connections to be made with very little effort.

A coupling consists of a nipple and socket. Connections are made by pushing a socket onto a nipple. The sliding sleeve then engages to provide a secure connection. This sleeve is pushed back to detach a connection. A spring then pushes the socket away from the nipple.

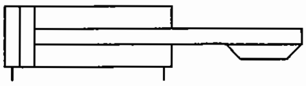
Coupling nipples can be screwed into the sub-bases. All valves mounted on sub-bases can thus be connected up via nipples. All other components should preferably also be equipped with nipples, and hoses should therefore be fitted with two sockets. Components such as shut-off valves or non-return valves which are connected on one side to hoses and on the other to components are equipped with coupling nipples and coupling sockets respectively.

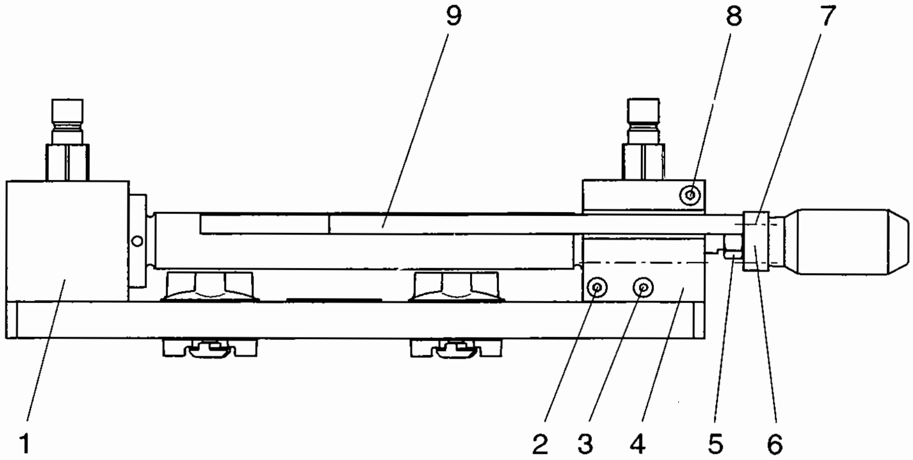


Self-closing coupling

Since the couplings close to create a leakproof seal, it may occur that pressure is trapped inside a component. If this happens, the force required to operate the coupling will increase to such an extent that the component cannot subsequently be coupled up again. The remedy in cases of this kind is to use a pressure relieving device. This is of similar design to a coupling socket but incorporates an adjustment spindle. The spindle should initially be rotated fully out and the device then pushed onto a nipple until the sliding sleeve engages. The spindle can be rotated inward to push back the sealing pin of the nipple and open the seal. The pressure behind the nipple will then be relieved; a drop of oil may escape during this operation. The pressure relieving device can be removed again by pushing back the sliding sleeve.

GB





Assembly
Double-acting cylinder (PN 152857) (1), cheese-head bolts (2) and (3), guide plate (4), lock nut (5), bolt-on plate (6), cheese-head bolts (7) and (8), guide rule (9).

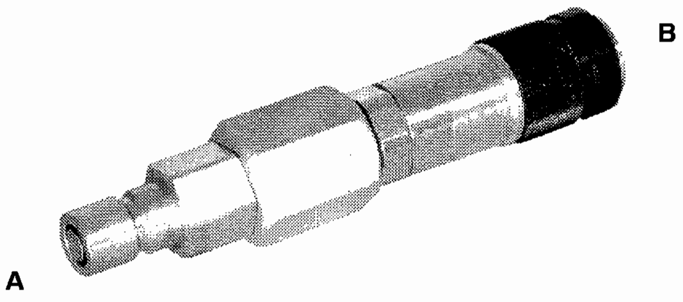
Function
Guide rule for actuation of trip cam
(e.g. stem-actuated valve PN 152978).

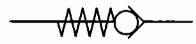
Fit the guide plate (4) to the side of the cylinder head, using the cheese-head bolts (2) and (8). Fit the bolt-on plate (6) to the piston rod. In order to do this, remove the cam, push in the bolt-on plate as far as the lock nut (5) and refit the cam. Insert the guide rule (9) into the slot of the guide plate (4) and secure the end face to the bolt-on plate (6) using cheese-head bolt (7).

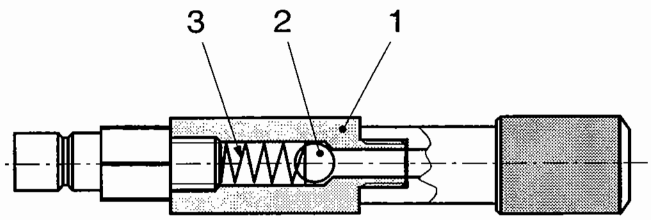
Note
It is possible to fit a potentiometer as follows. Use cheese-head bolt (3) to clamp the potentiometer into the 12.7 mm dia. hole in the guide plate (4) and screw the M4 thread into the bolt-on plate (6).

Technische Daten

Length of rule	200 mm
Divisions	150 mm : 50 mm
Mounting: Cheese-head bolts Lock nut	• M4 M8
Subject to change	







Design
Housing (1), sealing ball (2), spring (3), nipple (A), socket (B)

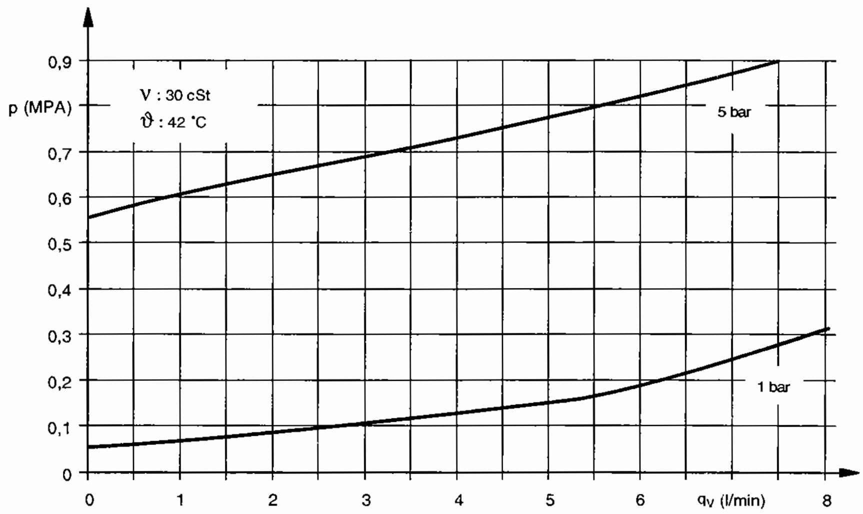
Function
A non-return valve prevents flow in one direction, while allowing free flow in the opposite direction.
In the closed position, the spring (3) presses the sealing ball (2) onto the valve seat.
Flow begins when the pressure in the flow direction exceeds a value of approx. 1 bar or 5 bar. The sealing ball (2) is then lifted off the valve seat against the force of the spring (3).

Note
Circuits must always be depressurised before a non-return valve is coupled up.
It is **not** possible in this case to release pressure by means of the pressure relief device PN 152971.

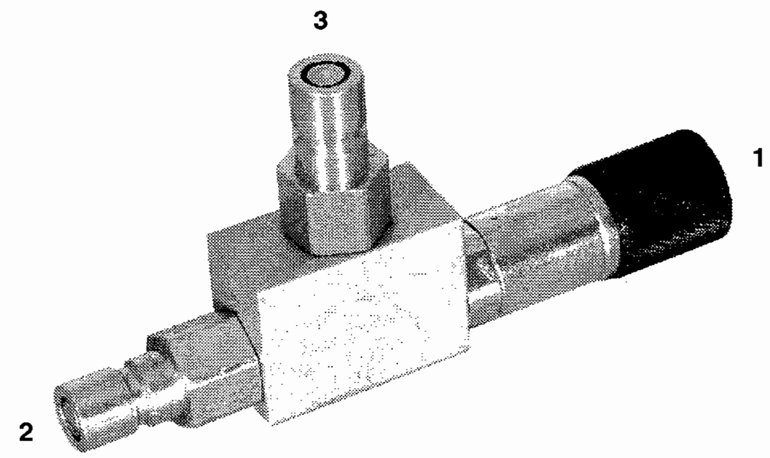
Technical data

Medium	Mineral oil, recommended viscosity 22 cSt (mm^2/s)
Operating pressure p	60 bar (6 MPa)
Max. permissible pressure p_{max}	120 bar (12 MPa)
Opening pressure	1 bar (0.1 MPa) with PN 152845 5 bar (0.5 MPa) with PN 152846
Actuation	Hydraulic
Connections	For coupling nipple/socket
Subject to change	

Pressure-drop/
flow-rate characteristic

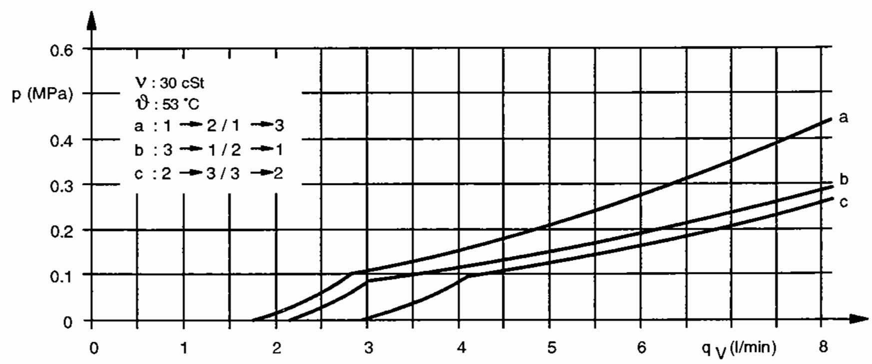


Branch tee



Design
Branch tee with 3 connections (1 = socket, 2 and 3 = nipples)

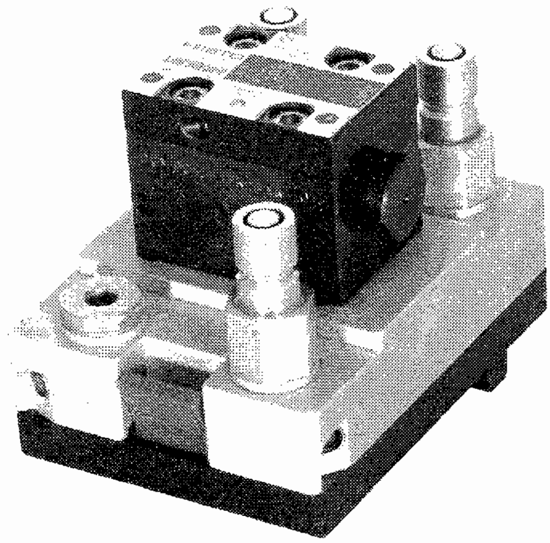
Function
This component can be fitted at any desired point to create a branch.

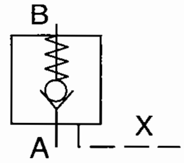


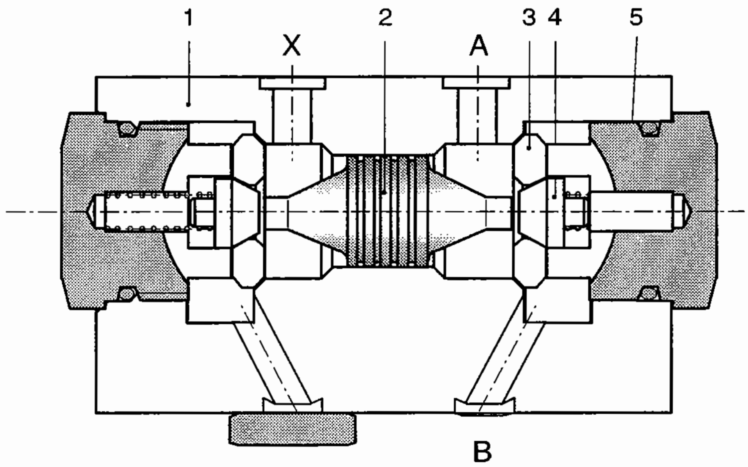
Pressure-drop/ flow-rate characteristic

Medium	Mineral oil, recommended viscosity 22 cSt (mm^2/s)
Operating pressure p	60 bar (6 MPa)
Max. permissible pressure p_{max}	120 bar (12 MPa)
Connections	For coupling nipple/socket
Subject to change	

Technical data

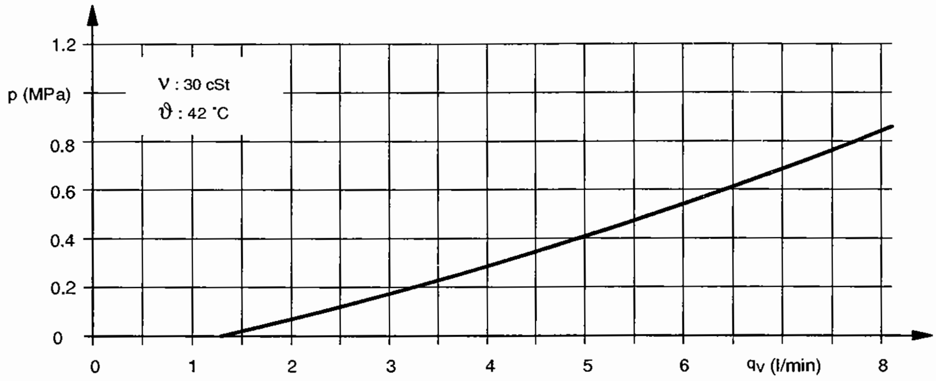






Design
This hydraulically piloted non-return valve is mounted on a function plate equipped with three connection nipples. The component is fitted to the grid system of the profile plate by means of the two blue levers (mounting variant “A”).
The valve consists of:
Housing (1), release piston (2), valve seat (3), sealing cone (4) spring (5).

Function
In the closed position, the sealing cone (4) is pressed onto the valve seat (3) by the spring (5). Flow from B to A is disabled.
The closed position is cancelled by applying pressure to the pilot port X. The released piston (2) lifts the sealing cone (4) away from the valve seat (3), enabling flow from B to A.



Pressure-drop/ flow-rate characteristic

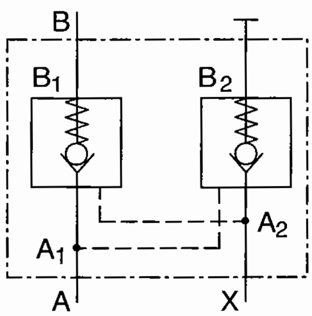
Note

The valve ports are identified by letters.

A, B Working ports
X Pilot port

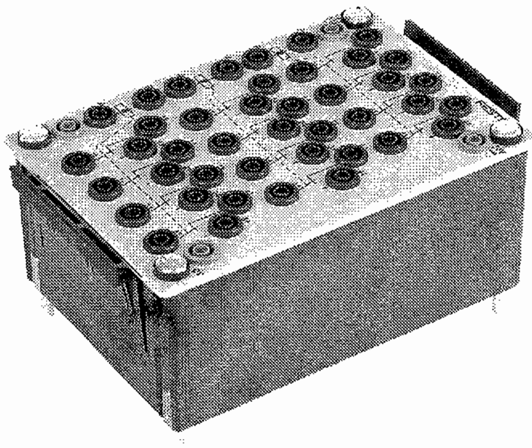
Double non-return valve, hydraulically piloted

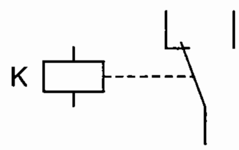
As illustrated by the sectional view, the valve design corresponds to a non-return valve with piloted release in two directions. By using a coupling nipple PN 342047 a double non-return valve with piloted release in one direction will be produced (see symbol).



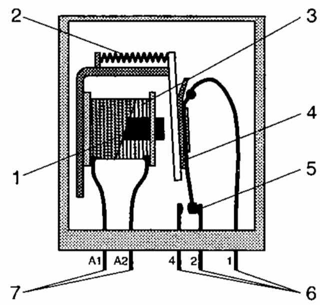
Technical data

Medium	Mineral oil, recommended viscosity 22 cSt (mm^2/s)
Operating pressure p	60 bar (6 MPa)
Max. permissible pressure p_{max}	120 bar (12 MPa)
Actuation	Hydraulic (3.3 : 1)
Connections	For 3 coupling sockets
Subject to change	



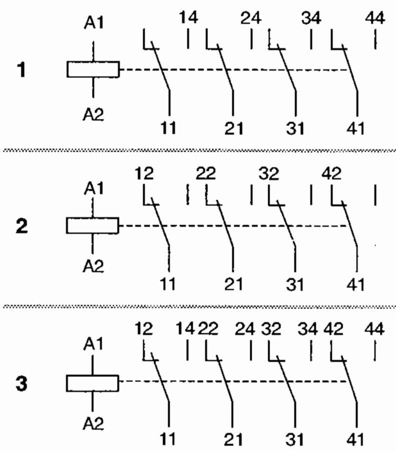


Design
This component consists of three relays with connections and two bus-bars for the power supply. All electrical connections are in the form of 4 mm sockets. The unit can be mounted in a mounting frame or on the profile plate using four plug-in adapters.



Function
The relay consists of a coil with a core (1) and winding (3) with connection lugs (7), an armature (4), a return spring (2) and a contact assembly with four changeover contacts (5) and connection lugs (6). When power is applied to the coil connections, current flows through the winding, creating a magnetic field. The armature is pulled onto the coil core and the contact assembly is actuated. Electrical circuits are opened or closed via this assembly. When the electrical current is removed, the magnetic field collapses and the armature and contact assembly are returned to their original position by a return spring.

Note
The switching status of the relays is indicated by LEDs, which are protected against incorrect polarity.
The four changeover contacts of the contact assembly can be used as normally-open contacts (1), normally-closed contacts (2) or changeover contacts (3).

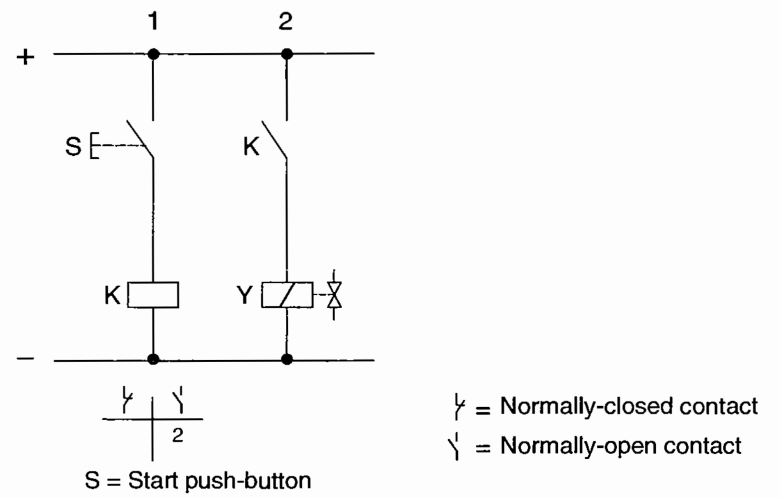


Voltage	24 V DC
Contact assembly	4 changeover contacts
Contact rating	Max. 5 A
Contact interrupt rating	Max. 90 W
Pichup time	10 ms
Drop-off time	8 ms
Connections	For 4 mm safety connector plug
Electromagnetic compatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	

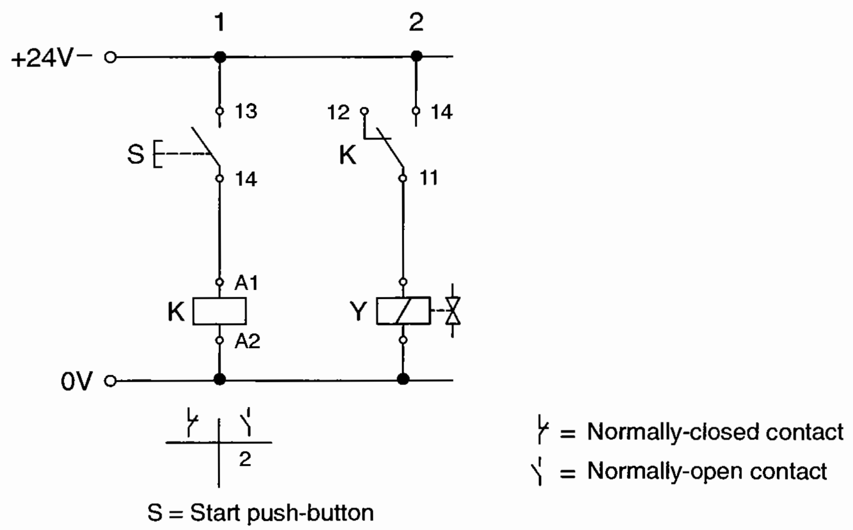
CE

Technical data

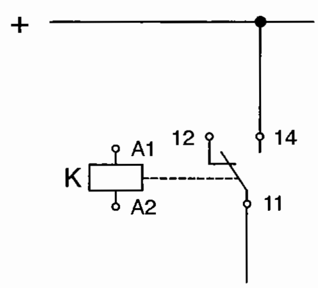
Example of application: Circuit diagram, electrical



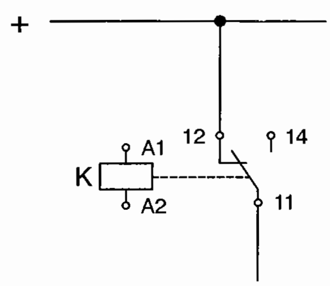
Example of application: Practical assembly, electrical



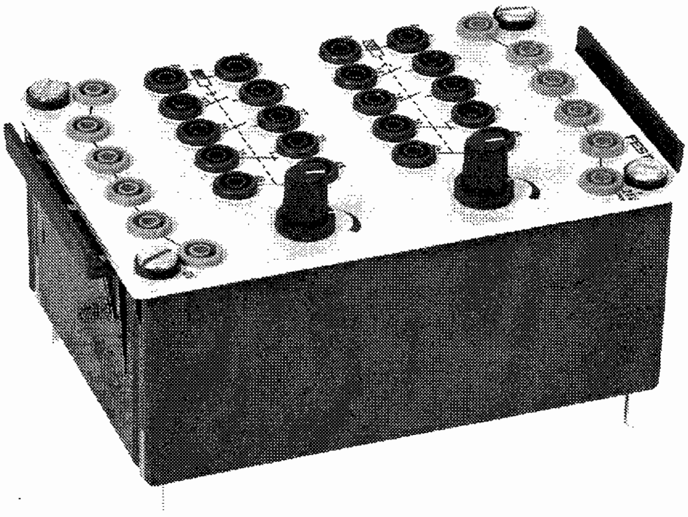
Normally-open contacts, normally-closed contacts: Allocation of contacts on relay plate

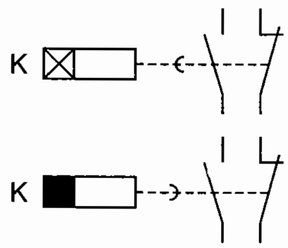


Changover switch connected as n.o. contact



Changeover switch connected as n.c. contact





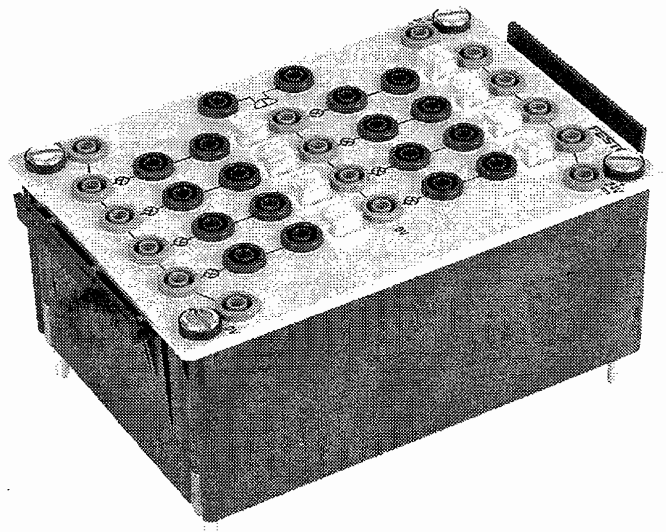
Design
The unit consists of two printed circuit boards with one switch-on and one switch-off relay with time delay, mounted on a plug-in plate. All electrical connections are in the form of 4 mm safety connectors. The unit can be mounted in a mounting frame or on the profile plate using four plug-in adapters.

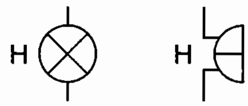
Function
The time period of the **relay with switch-on delay** can be infinitely adjusted via the rotary knob of the potentiometer. The contact set consists of two normally open contacts and two normally closed contacts. When the voltage is applied to the coil connections, the set time delay takes effect. When the time delay has expired, the contact set is actuated. Circuits are opened or closed via the contact connections. When the time delay has expired, the contact set returns to its initial position without delay. A protective circuit protects the switch-on delay time relay against polarity reversal.
The time period of the **switch-off** time relay is infinitely adjustable via the rotary knob of the potentiometer. The contact set consists of two normally open contacts and two normally closed contacts. The contact set is actuated without delay when the voltage is applied. Circuits are opened or closed via the contact connections. When the voltage is removed, the set time delay takes effect. When the time delay has expired, the contact set is returned to its initial position. The switch-off time relay is protected against polarity reversal.

Note
The correct polarity must be observed for proper function in industrial use.

Voltage	24 V DC
Contact set	2 normally open, 2 normally closed contacts
Contact load	maximum 5 A
Cut-off capacity	maximum 100 W
Time delay	0.5 to 10 s (adjustable)
Connection	For 4 mm safety connector plug
Electromagnetic compatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	

Technical data





Design
This component consists of an acoustic indicator and four visual indicators with connections and three busbars for the power supply. All electrical connections are in the form of 4 mm safety connectors. The unit can be mounted in a mounting frame or on the profile plate using four plug-in adapters.

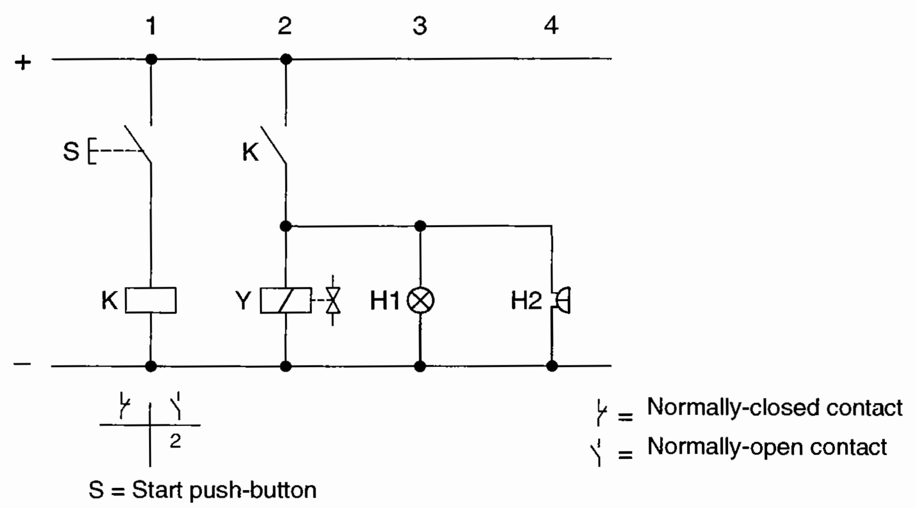
Function
The **acoustic indicator** outputs a buzzing tone when power is applied to its connections.
The **visual indicator** consists of a housing and a colourless transparent cap with a miniature lamp. When power is applied to its connections, its operating status is indicated by the built-in miniature lamp. A bridged pair of sockets is provided for each lamp, allowing the component to be used also as a distributor.

Note
To ensure that the **acoustic indicator** operates correctly, check the polarity of the power supply.

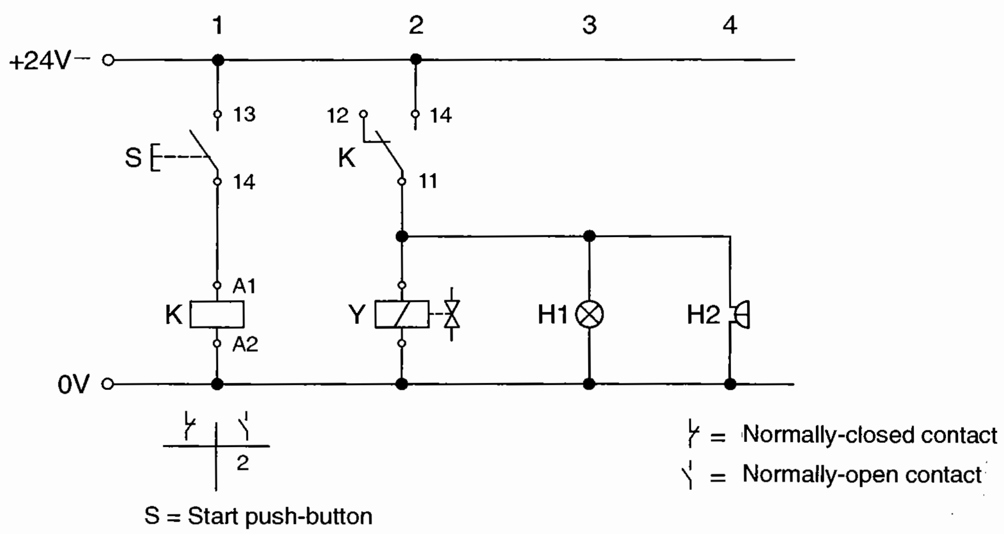
Voltage	24 V DC
Power consumption (acoustic indicator)	0.04 W
Visual indicator	1.2 W
Frequency (acoustic indicator)	420 Hz
Connection	For 4 mm safety connector plug
Electromagnetic compatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	

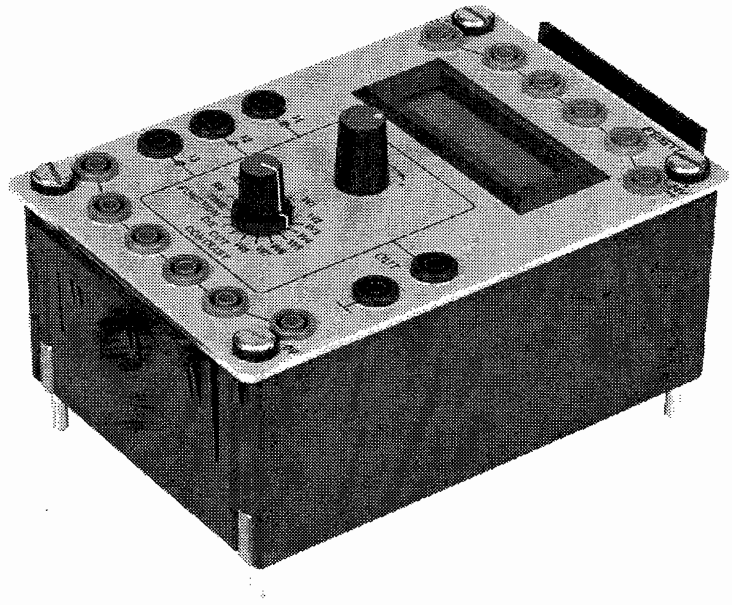
Technical data

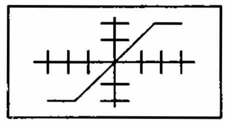
Example of application:
Circuit diagram,
electrical

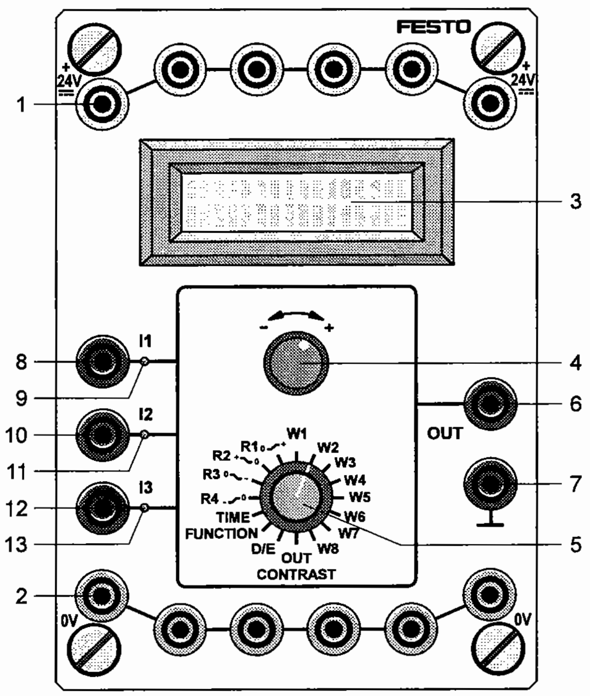


Example of application:
Practical assembly,
electrical









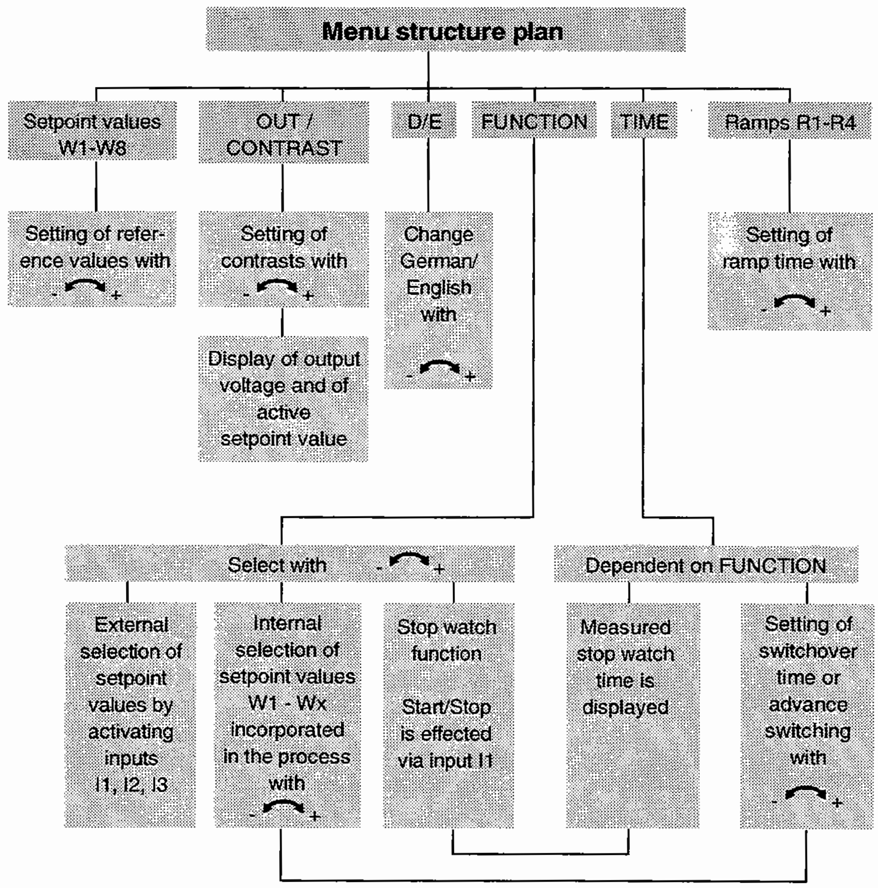
Front view

Control elements

1	Supply voltage: 24 VDC	8	External binary input I1
2	Supply voltage: 0 VDC	9	LED
3	Display	10	External binary input I2
4	Turning knob	11	LED I2
5	Selector switch	12	External binary input I3
6	Setpoint signal +	13	LED I3
7	Setpoint signal -		

Design
The setpoint value card is housed inside a small ER unit. The signals and voltages can be accessed via 4 mm safety connectors. The unit is mounted in the cabinet frame of the laboratory workstation or on the profile plate by means of four plug-in adapters.

Function
The functions of the setpoint value card are as follows:
- programmable setpoint value generation
- programmable ramp generation
- cyclical sequence of setpoint values and ramps
- Stop watch



Menu structure plan

Storing
The set values are stored by means of further detenting of the selector switch.

Stop watch
The stop watch function is selected via the menu item "FUNCTION". The measured time is displayed under the menu item "TIME". The stop watch is started and stopped by means of setting at input I1. The maximum measuring time is 100 hours.

Setpoint values
Up to 8 setpoint values can be set between the voltage range of -10 V to +10 V. These can be activated internally or externally.
Internal activation is effected sequentially within the adjustable reversing time (0.01...50 sec.). The reversing time is identical for all setpoint values. The external control inputs I1, I2 and I3 are inactive.
With switchover times of less than 0.01 sec. or more than 50.0 sec., the operating mode "Advance switching setpoint values" is selected, where the internally selected setpoint values W1...Wx are continually advanced, once the actived setpoint value has reached its value.

Bit table of inputs			
I3	I2	I1	Setpoint value
0	0	0	W1
0	0	1	W2
0	1	0	W3
0	1	1	W4
1	0	0	W5
1	0	1	W6
1	1	0	W7
1	1	1	W8

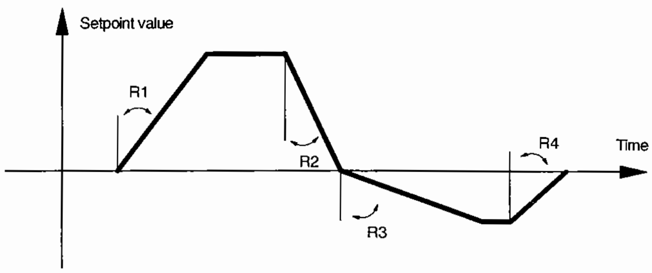
Bit table

External activation is effected in any order according to the bit table via activation of the inputs I1, I2 and I3. The internal reversing time is inactive.

Ramps

The ramps are set as slope parameters (seconds / Volt), i.e.:

- low ramp value = large slope
- high ramp value = small slope



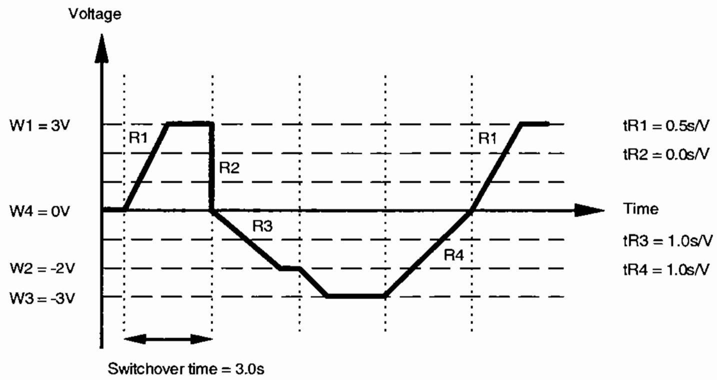
The ramps in the quadrants of the cartesian coordinate system are defined as follows:

1. Quadrant: positive slope of 0 V
2. Quadrant: negative slope up to 0 V
3. Quadrant: negative slope of 0 V
4. Quadrant: positive slope up to 0 V

Supply voltage	24 V DC +/- 10%
Number of setpoint values	8
Output voltage range	-10V...+10V Tol. ± 5 mV (adjustable in steps of 0.1 V)
Number of ramps	4
Ramp times	0...10.0 s / 1V (adjustable in steps of 50 ms / 1V)
Activating voltage of inputs	min. 15 V
Output rate	1 kHz
Stop watch	Input I1 Measuring time 0...100 Std.
Connections	For 4 mm safety connector plug
Electromagnetic combatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	

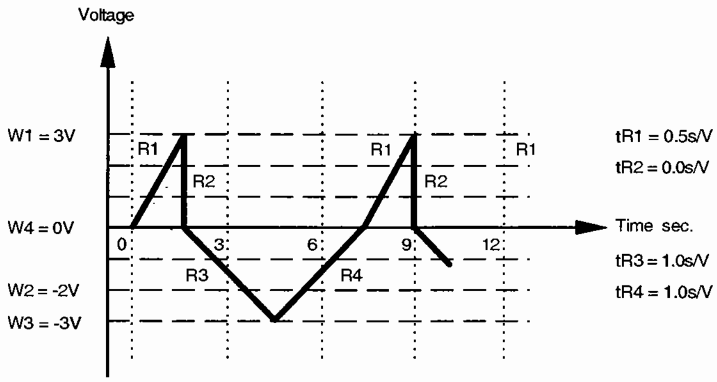
CE

Technical data



Example 1
Settings at setpoint value card:

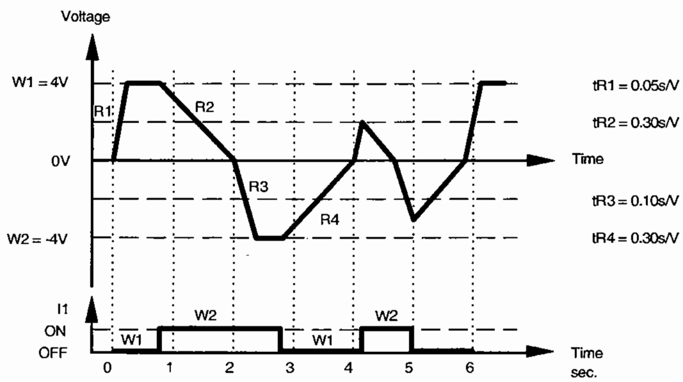
Function:	Internal selection:
	Setpoint values 1÷4
Time:	Switchover time t = 3.0s
Ramp times:	tR1 = 0.5s/V
	tR2 = 0.0s/V
	tR3 = 1.0s/V
	tR4 = 1.0s/V
Setpoint values:	W1 = 3.0V
	W2 = -2.0V
	W3 = -3.0V
	W4 = 0.0V



Example 2
Settings at setpoint value card:

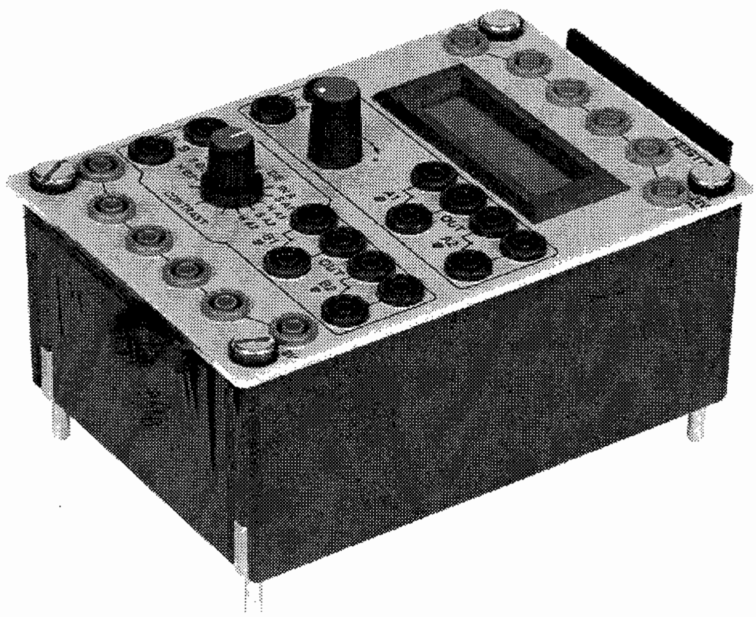
Time: Advance switching setpoint values

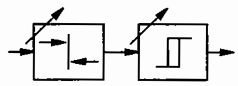
All other settings identical to example 1.

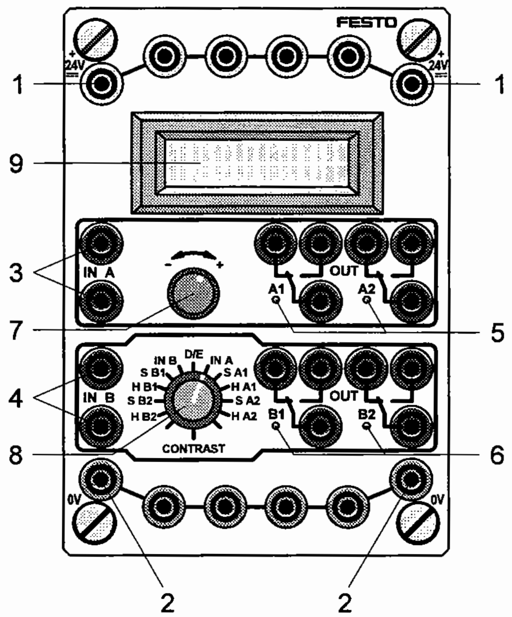


Example 3
External activation via input I1

Function:	Select setpoint values
	with I1, I2, I3
Ramp times:	tR1 = 0.05s/V
	tR2 = 0.30s/V
	tR3 = 0.10s/V
	tR4 = 0.30s/V
Setpoint values:	W1 = 4.0V
	W2 = -4.0V







Key to operator facilities

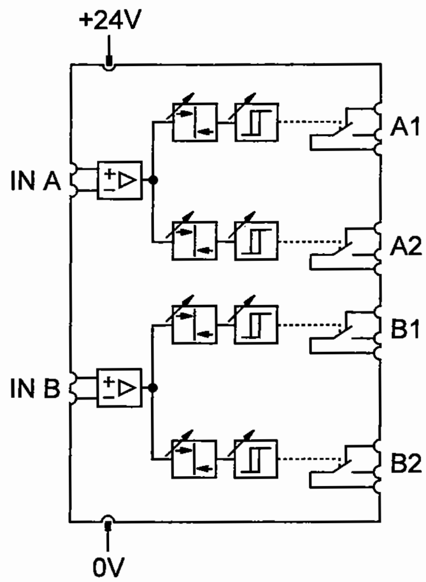
1 Power supply + 24 V
2 Power supply 0 V
3 Input A, input voltage 0 ...+/- 10 V
4 Input B, input voltage 0 ...+/- 10 V
5 Output contacts A1, A2
6 Output contacts B1, B2
7 Adjusting knob
8 Selector switch
9 Display

Design
This comparator card has two separate inputs (IN A, IN B), each of which acts on one of two independent comparators. The outputs of these are designated OUT A1, A2 and OUT B1, B2. The activation of outputs is shown by LEDs.

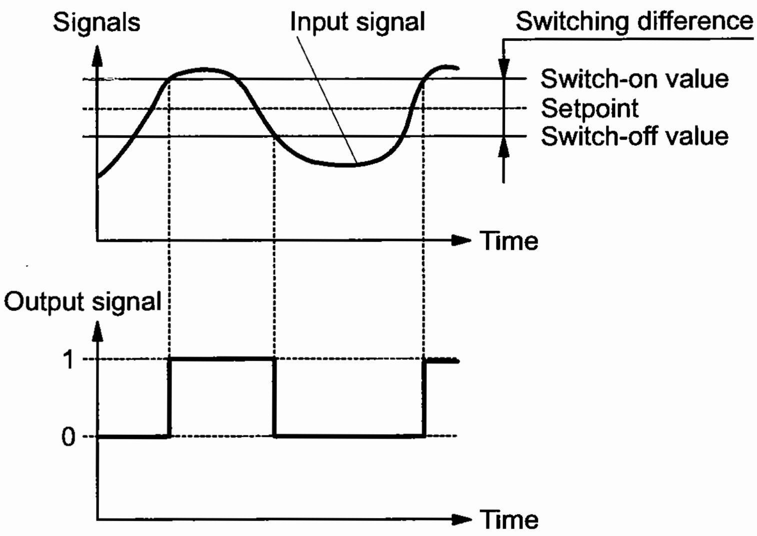
The following values can be set on each comparator:
– Setpoint voltage: -10 V ... +10 V,
– Hysteresis (switching difference): 0 V ... 5 V.

The switch-on and switch-off values are defined as follows:
– Switch-on value = Setpoint +1/2 hysteresis,
– Switch-off value = Setpoint –1/2 hysteresis.

The setpoints and hysteresis values are selected by means of a selector switch. The settings are made with the aid of an adjusting knob. The contrast of the LCD is adjustable. The menu guidance system also offers a choice of German and English language.
The power supply for the comparator card is 24 V.



Function
A positive-switching comparator with switching difference has the following characteristics:
- The output is set when the input signal exceeds the switch-on value.
- The output is reset when the input signal falls below the switch-off value.

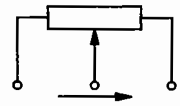


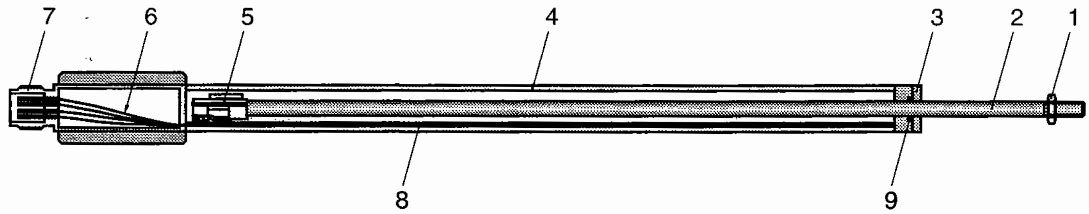
Mode of operation of a positive comparator with switching difference

Power supply	24 V DC +/- 10%
Input voltage inputs A and B	-10 V...+10 V
Input resistance inputs A and B	> 10 kOhm
Display accuracy	+/- 30 mV
Outputs A and B	Floating relay contacts, changeover contacts
Contact rating	24 V DC / 2 A 120 V AC / 1 A
Connection	for 4 mm safety connector plug
Electromagnetic compatibility Emitted interference	 tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	

Technical data

The inputs are short-circuit proof and surge-proof up to 24 V.

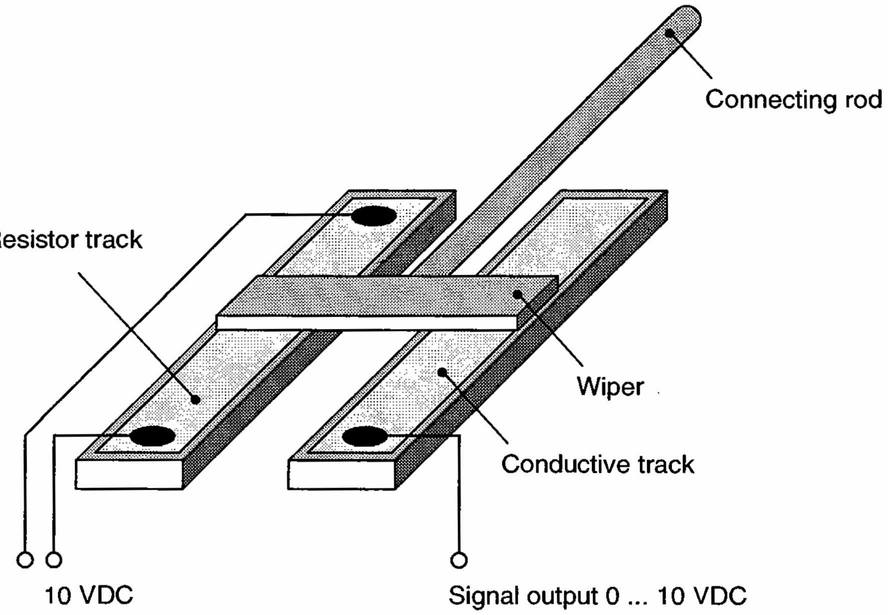




Design

The linear potentiometer is mounted on to the cylinder (Pt. No. 152857) with the mounting kit (Pt. No. 120778).

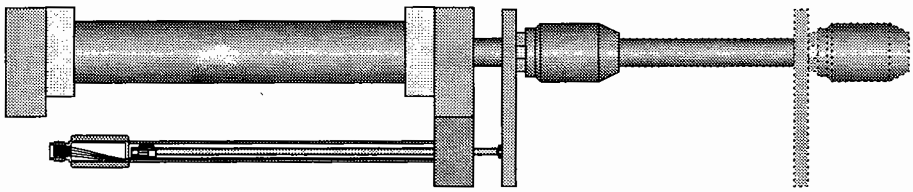
1 Attachment lock nut
2 Connecting rod
3 Cover cap with bearing
4 Light metal housing
5 Retainer for wiper
6 Electrical connection
7 Wiring box
8 Plastic film wiper track
9 Scraper ring

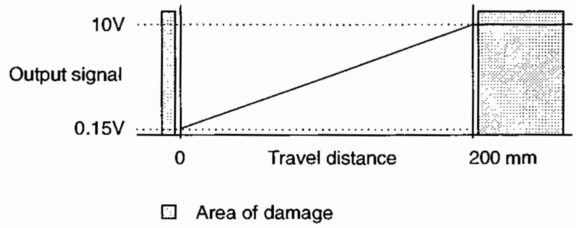


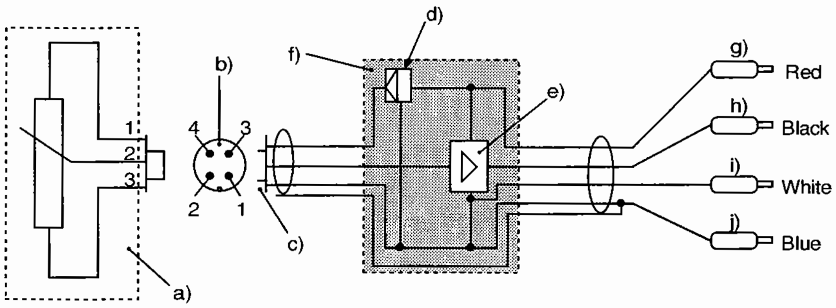
Function
Two plastic film wiper tracks are located along the inside of the light metal housing (4). One track represents the electrical resistor, the other acts as the conductive track. The wiper bridges the two tracks. The ends of the resistor track are connected electrically via a connection socket. A voltage is applied to these connections and subsequently drops via the resistor track. Depending on the position of the wiper or the connecting rod, a voltage is now tapped, which is proportional to the position.

Installation and connection of the displacement encoder
The linear potentiometer is connected by means of a special cable. This cable contains an electronic module, which protects the potentiometer from incorrect connection and from excessive electrical loads.
The displacement encoder is to be installed with the cylinder extended. The connecting rod is screwed into the drive plate of the cylinder and locked. Then, the potentiometer housing is pulled back up until the mechanical end stop has been reached. For the subsequent precision adjustment, it is necessary to connect the potentiometer electrically. The housing is then in the correct position when the output signal displays 9.99 V or just 10.00 V. (There are no output signal values greater than 10 V).
Now lightly clamp the housing.
Then check the output voltage and the position of the housing in the retracted status of the cylinder.
The position of the housing must not be moved during this and the output signal should not be below 150 mV.
Now completely tighten the housing clamp.

Warning
The potentiometer must be installed and secured with the greatest of care, as it may be damaged if the mechanical end stop is overtravelled.
Therefore check that the stroke of the potentiometer is sufficient and that movements cannot exceed the mechanical end stop.



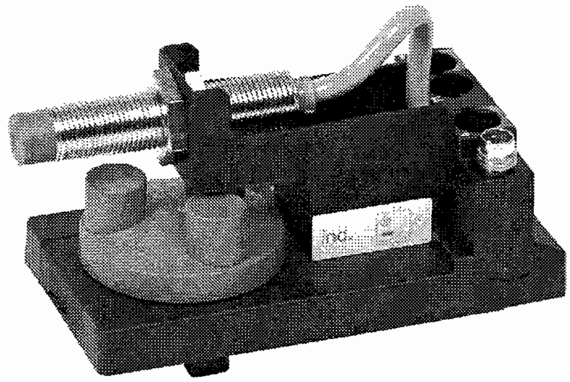


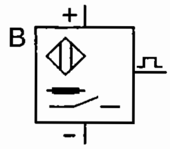


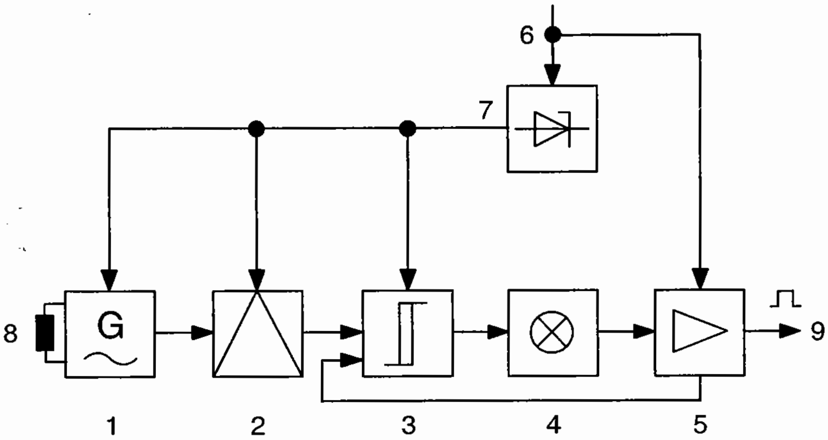
a) Potentiometer
b) Pin assignment
c) Plug
d) Reference voltage supply
e) Impedance converter
f) Housing
g) Supply voltage
h) + Signal
i) - Signal
j) Supply earth

Technical data

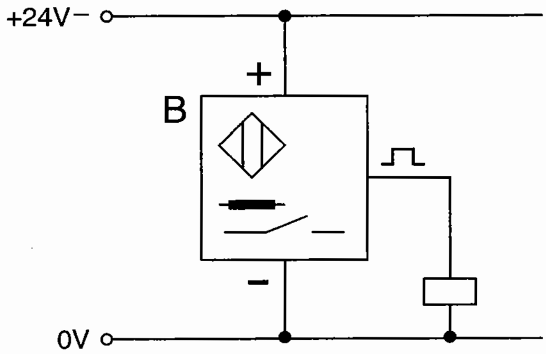
Connection cable	
Supply voltage	13 ... 30 VDC
Output voltage	0 ... 10 VDC
Potentiometer	
Measuring stroke	200 mm
Electrical resistance	10 KOhm ± 20 %
Load carrying ability	4 W
Linearity tolerance	0.5 %
Mechanical stroke	201 mm
Service life	25,000 000 Wiper cycles
Max. wiper current	≤ 1 mA
Max. pick-up speed	1.5 m/s
Operating temperature range	- 40 °C bis + 105 °C
Protection class	IP 64
Mechanical attachment of connecting rod	M4 thread
Subject to change	







1 Oscillator
2 Demodulator
3 Trigger stage
4 Operating status display
5 Output stage with protective circuit
6 External voltage
7 Internal constant voltage supply
8 Coil with active zone
9 Switching output



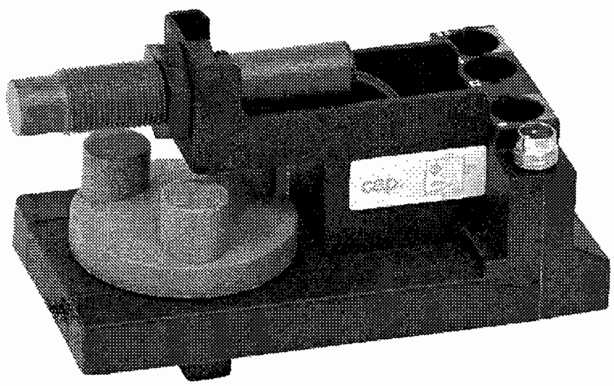
Design
The inductive proximity sensor with LED and electrical connections is assembled on a polymer assembly base. The electrical connection is effected by means of safety connectors or via a 3-pin plug socket. The unit is mounted on the profile plate via a quick release detent system with blue triple grip nut (Mounting alternative "B").

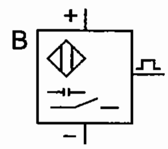
Function
The inductive proximity sensor consists of an oscillator circuit, which is made up of a parallel resonant circuit with coil and capacitor as well as an amplifier. The electromagnetic field is directed outwardly by means of a ferrite shell core.
When a electrically conductive material is brought into the electromagnetic stray field, this creates eddy currents in the material in accordance with the law of induction, which attenuate the oscillator. Depending on the conductivity, the size and proximity of the conducting object, the oscillator may be attenuated so strongly that oscillation ceases. The attenuation of the oscillator is evaluated in the triggering stage which supplies an output signal.
The proximity sensor has a PNP output, i.e. the signal line is switched to a positive potential in the switched status. The switch is designed in the form of a normally open contact. The connection of the load takes place between the signal output of the proximity sensor and the load. The active surface can be identified by a blue polymer disc. The operating status is indicated via an LED display. The sensor is protected against polarity reversal, overload and short circuit.

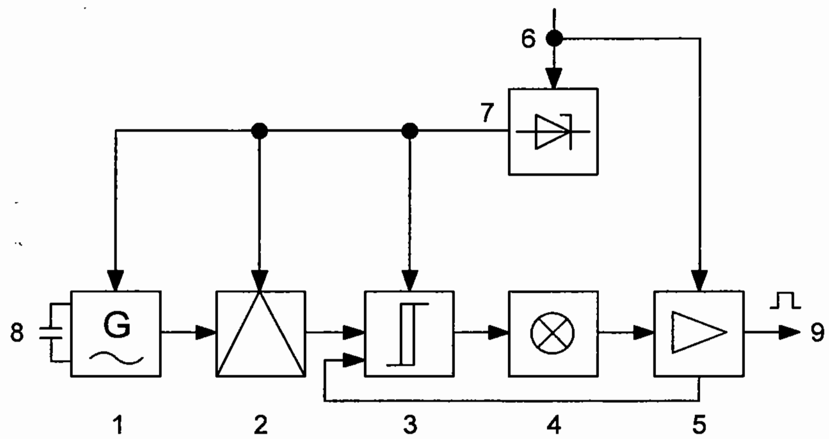
Note
The correct polarity of the applied voltage is necessary for proper functioning. The connections for the operating voltage are colour coded as follows: red for positive, blue for negative and black for the signal output. The load is connected to the switching output and connected to the negative terminal of the current supply.

Technical data

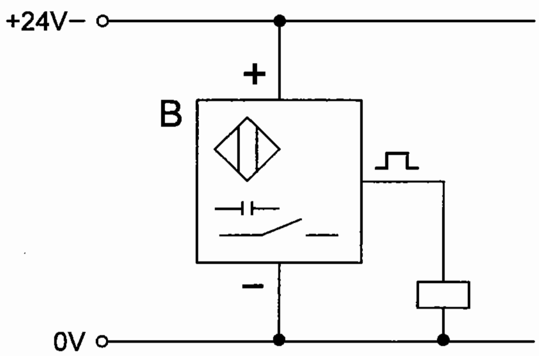
Switching voltage	10 to 30 V DC
Residual ripple	max. 10% to DIN 41755
Nominal switching distance	4 mm (material: mild steel)
Switching frequence	max. 800 Hz
Output function	normally open contact, positive switching
Output current	max. 400 mA
Protection class	IP65
Connections	for 4 mm safety connector plug or 3-pin socket
Electromagnetic compatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	







1 Oscillator
2 Demodulator
3 Trigger stage
4 Operating status display
5 Output stage with protective circuit
6 External voltage
7 Internal constant voltage supply
8 Capacitor with active zone
9 Switching output



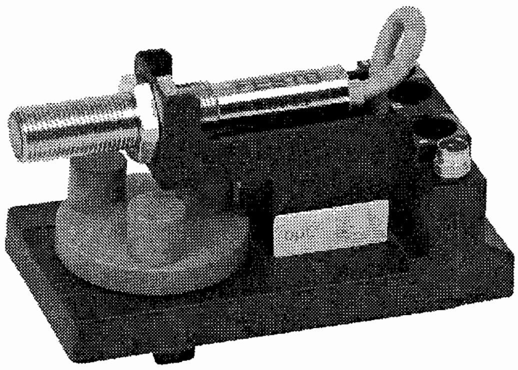
Design
The capacitive proximity sensor with LED and electrical connections is assembled on a polymer assembly base. The electrical connection is effected by means of safety connectors or via a 3-pin plug socket. The unit is mounted on the profile plate via a quick release detent system with blue triple grip nut (mounting alternative “B”).

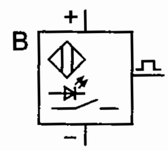
Function
The operational principle of a capacitive sensor is based on the evaluation of the capacity change of a capacitor in a RC resonant circuit.
When a material approaches the proximity sensor, the capacity of the capacitor is stimulated (increased), whereby the change in the oscillatory characteristics of the RC circuit can be evaluated. The capacity change largely depends on the distance, size and dielectric constant of the material used.
The proximity sensor has a PNP output, i.e. the signal line is switched to a positive potential in the switched status. The switch is designed as a normally open contact. The connection of the load takes place between the signal output of the proximity sensor and the load. A yellow LED indicates the switching status. The sensor is protected against polarity reversal, overload and short circuit.

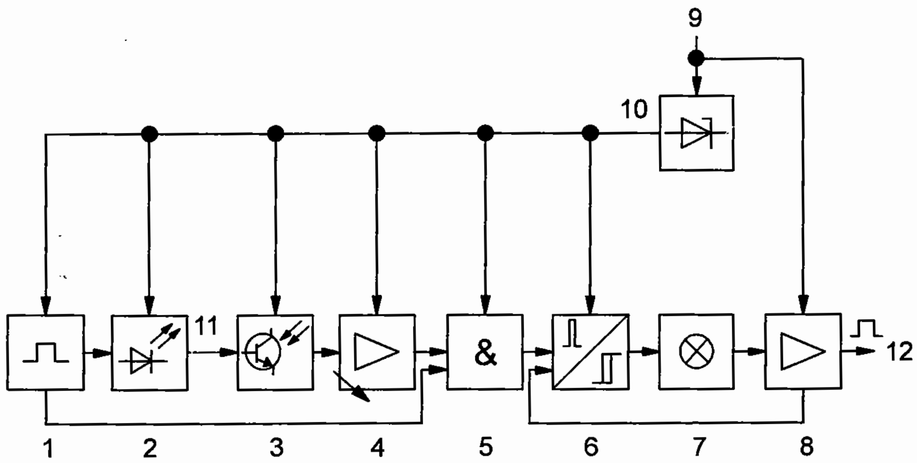
Note
The correct polarity of the applied voltage is to be observed for proper functioning. The connections for the operating voltage are colour coded as follows, red for positive, blue for negative and black for the signal output. The load is connected to the switching output and linked to the negative terminal of the current supply.

Technical Data

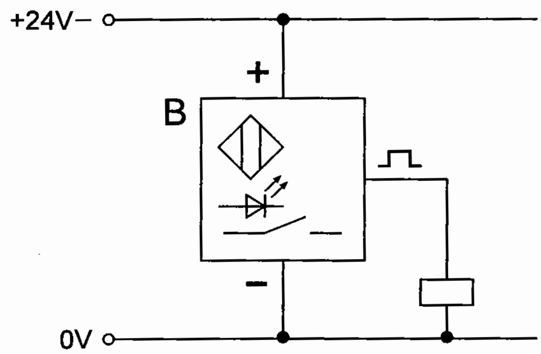
Switching voltage	10 to 30 V DC
Residual ripple	maximum 10%
Nominal switching distance	4 mm
Reproducible switching point at constant temperature	$\leq$ 0.01 mm
Switching frequency	maximum 100 Hz
No-load current	approx. 15 mA
Output current	maximum 200 mA
Switching capacity	maximum 4.8 W
Output function	Normally open contact, positive switching
Protection class	IP65
Connenction	for 4 mm safety connector plug or 3-pin socket
Electromagnetic compatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	







1 Oscillator
2 Photoelectric emitter
3 Photoelectric receiver
4 Preamplifier with potentiometer
5 Logic function
6 Pulse/level converter
7 Operating status display
8 Output stage with protective circuit
9 External voltage
10 Internal constant voltage supply
11 Optical path
12 Switching output



Design
The optical proximity sensor with LED and electrical connections is assembled on a polymer assembly base. The electrical connection is effected by means of safety connectors or via a 3-pin plug socket. The unit is mounted on the profile plate via a quick release detent system with blue triple grip nut (mounting alternative "B").

Function
Optical proximity sensors consist of two main modules, the emitter and the receiver. In the case of diffuse sensor, these are built into one housing.
The emitter of the diffuse sensor emits a pulsating, red light which is within the visible spectral range. The object to be detected reflects part of the light emitted. This light is detected by a semiconductor device in the receiver which is also built into the sensor housing and causes a change in the switching status.
The object to be detected may be reflective, matt, transparent or opaque. All that is needed is for a sufficiently high proportion of light to be reflected directly or diffusely. The operational switching distance may be varied by means of a potentiometer.
The proximity sensor has a PNP output, i.e. the signal line is switched to the positive potential in the switched status. The switch is designed as a normally closed contact. The connection of the load takes place between the signal output of the proximity sensor and the load. The switching status is indicated by a yellow LED. The sensor is protected against polarity reversal, overload and short circuit.

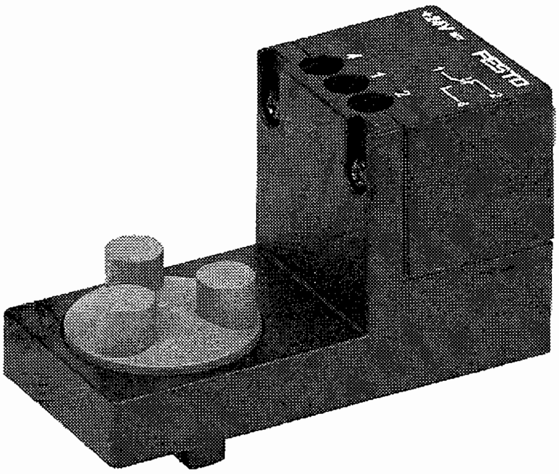
Note
The correct polarity of the applied voltage is necessary for proper functioning. The connections for the operating voltage are colour coded as follows: red for positive, blue for negative and black for the signal output. The load is connected to the switching output and the negative terminal of the current supply.

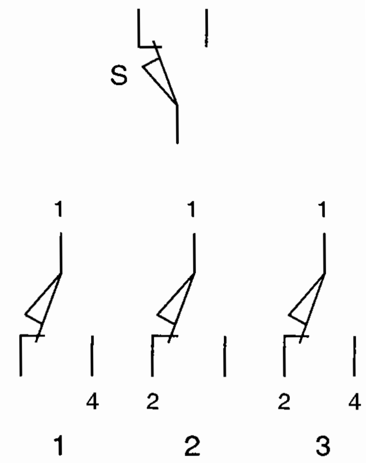
Technical Data

Switching voltage	10 to 30 V DC
Residual ripple	maximum 10%
Nominal switching distance	0 to 100 mm (adjustable)
Switching frequency	maximum 200 Hz
Output function	Normally open contact, positive switching
Output current	maximum 100 mA
Protection class	IP65
Connections	for 4 mm safety connector plug or 3-pin socket
Electromagnetic compatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	

Limit switch, electrical, actuated from the left

183322

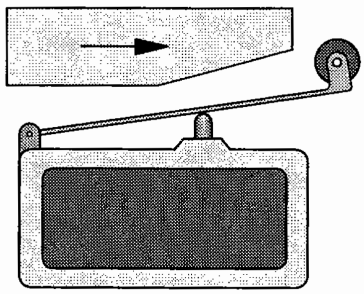




The two electrical limit switches, PN 183322 for actuation from the left and PN 183345 for actuation from the right, have the same symbol in the circuit diagram.

Design
A microswitch with roller lever and electrical connections is installed in a plastic housing. The electrical connection is effected by means of safety connectors or via a 3-pin plug socket. The component is mounted on the profile plate using the rotary system by means of two blue grip nuts (mounting variant "B").

Function
This electrical limit switch consists of a mechanically-actuated microswitch. It is actuated when the roller lever is pressed, for example by the trip cam of a cylinder. The switch contacts are used to open or close a circuit. The microswitch returns to its original position when the roller lever is released.

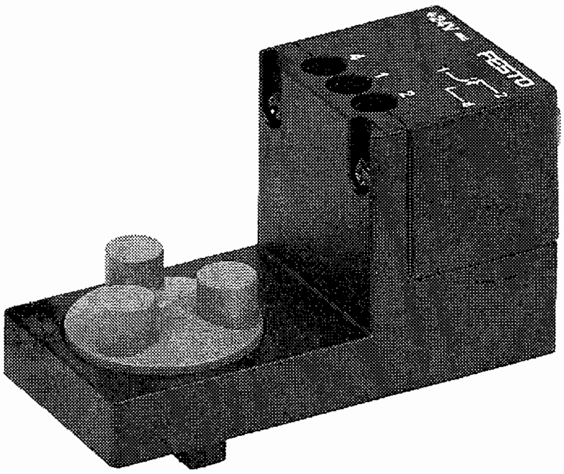


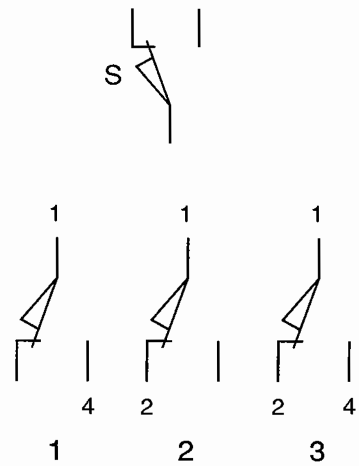
Note
The microswitch can be connected up to act as a normally-open contact (1), normally-closed contact (2) or changeover contact (3). In cases where piston speeds are high, the limit switch should be actuated by the trip cam of a cylinder only in the specified direction. The limit switch must not be actuated from the front.

Design	Mechanically-actuated electrical microswitch in limit-switch housing
Voltage	24 V DC
Contact rating	Max. 5 A
Switching frequency	Max. 200 Hz
Reproducible switching accuracy	0.2 mm
Switch travel	2.7 mm
Actuation force	5 N
Connections	For 4 mm safety connector plug or 3-pin plug socket
Electromagnetic compatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	

CE

Technical data

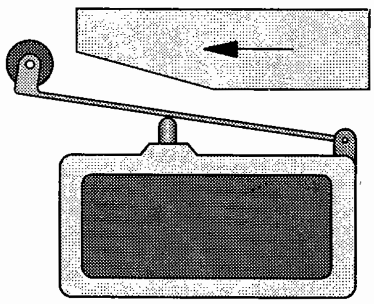




The two electrical limit switches, PN 183345 for actuation from the left and PN 183322 for actuation from the right, have the same symbol in the circuit diagram.

Design
A microswitch with roller lever and electrical connections is installed in a plastic housing. The electrical connection is effected by means of safety connectors or via a 3-pin plug socket. The component is mounted on the profile plate using the rotary system by means of two blue grip nuts (mounting variant "B").

Function
This electrical limit switch consists of a mechanically-actuated microswitch. It is actuated when the roller lever is pressed, for example by the trip cam of a cylinder. The switch contacts are used to open or close a circuit. The microswitch returns to its original position when the roller lever is released.

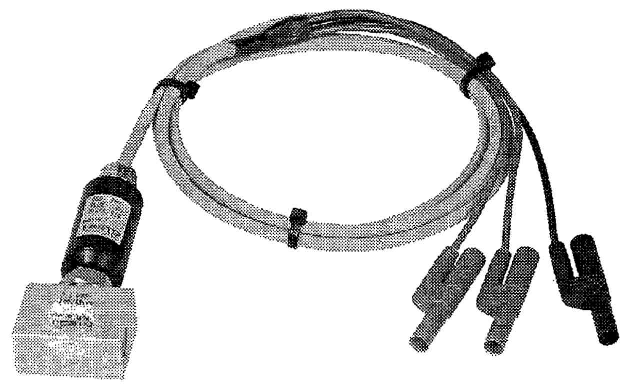


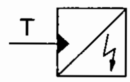
Note
The microswitch can be connected up to act as a normally-open contact (1), normally-closed contact (2) or changeover contact (3). In cases where piston speeds are high, the limit switch should be actuated by the trip cam of a cylinder only in the specified direction. The limit switch must not be actuated from the front.

Design	Mechanically-actuated electrical microswitch in limit=switch housing
Voltage	24 V DC
Contact rating	Max. 5 A
Switching frequency	Max. 200 Hz
Reproducible switching accuracy	0.2 mm
Switch travel	2.7 mm
Actuation force	5 N
Connections	For 4 mm safety connector plug or 3-pin plug socket
Electromagnetic compatibility	
Emitted interference	tested to EN 500 81-1
Noise immunity	tested to EN 500 82-1
Subject to change	

CE

Technical data





Construction
The analogue temperature sensor is screwed into a T connector. It can be equipped with differing pairs of hydraulic couplings, e. g.:

- **leak-proof coupling**
  Quick coupling socket Order No. 342046
  Coupling nipple Order No. 342047
- **NG6 Coupling**
  Sealing coupling Order No. 227901
  Sealing nipple Order No. 224513

The couplings must be securely screwed into the connector. The electrical connection is established via the 4 mm plugs fitted to the connecting lead.

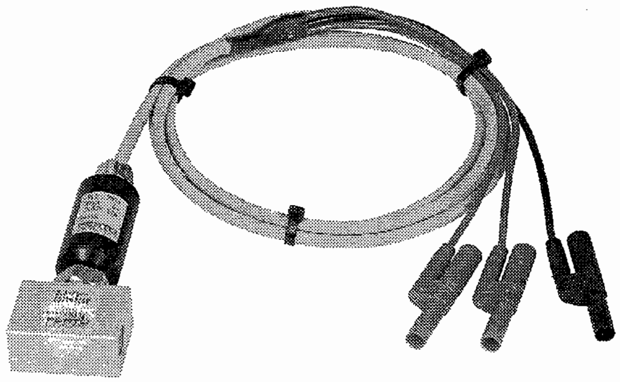
Function
Temperature is measured by a PT100 resistance thermometer, which operates on the principle that the electrical resistence of platinum varies in proportion to changes in temperature. Platinum has a positive temperature coefficient, i. e. its resistance increases as the temperature rises. This resistance change is electronically converted and amplified.

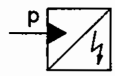
Note
Please observe the polarity of the connected voltage during operation. The terminal plugs have been colour coded.

Operating pressure	Positive terminal	red
	Negative terminal	blue
analogue output signals	Voltage	black

Technical data

Permissible operating voltage	20...30 VDC
Voltage output	0...10 V
Load resistance	> =4.7 kOhm
Measuring range	0...100 bar
Ambient operating temperature	-10 ... + 100 °C
Linearity	<= ± 0.5 % F.S.D.*
Reproducibility	<= ± 0.1 % F.S.D..*
Protection class (DIN 40 050)	IP 67
Weight	260g
Connection	cable with 4 mm plugs
* FSD full-scale deflection	
Subject to change	





Construction

The analogue pressure sensor is screwed into a T connector. It can be equipped with differing pairs of hydraulic couplings, e. g.:

- **leak-proof coupling**
  Quick coupling socket Order No. 342046
  Coupling nipple Order No. 342047
- **NG6 Coupling**
  Sealing coupling Order No. 227901
  Sealing nipple Order No. 224513

The couplings must be securely screwed into the connector. The electrical connection is established via the 4 mm plugs fitted to the connecting lead.

Function

A diaphragm inside the pressure sensor is distorted as a result of the measuring pressure applied. This distortion leads to a change in electrical resistance of the elements on the membrane (piezoresistive effect). This resistance change is electronically converted, temperature compensated and amplified.

Note

Please observe the polarity of the connected voltage during operation. The terminal plugs have been colour coded.

Operating pressure	Positive terminal	red
	Negative terminal	blue
analogue output signals	Voltage	black

Technical data

Permissible operating voltage	15...30 VDC
Voltage output	0...10 V
Load resistance	> =4.7 kOhm
Measuring range	0...100 bar
Critical frequency	1kHz
Ambient operating temperature	-10 ... + 70 °C
Temperature effect comp. range -10 °C ... 80 °C	± 0.2 % F.S.D.* / 10K
Linearity	<= ± 0.5 % F.S.D.*
Reproducibility	<= ± 0.1 % F.S.D..*
Protection class (DIN 40 050)	IP 67
Weight	260g
Connection	cable with 4 mm plugs
* FSD full-scale deflection	
Subject to change	