Fundamentals of servo motor drive technology
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Use for intended purpose

The training package for Basic Principles of Servo Motor Drive Technology may only be used:
- For its intended purpose in teaching and training applications
- When its safety functions are in flawless condition

The components included in the training package are designed in accordance with the latest technology, as well as recognised safety rules. However, life and limb of the user and third parties may be endangered, and the components may be impaired, if they are used improperly.

The training system from Festo Didactic has been developed and manufactured exclusively for training and vocational education in the field of automation technology. The respective training companies and/or trainers must ensure that all trainees observe the safety instructions which are described in this workbook.

Festo Didactic hereby excludes any and all liability for damages suffered by trainees, the training company and/or any third parties, which occur during use of the equipment set in situations which serve any purpose other than training and/or vocational education, unless such damages have been caused by Festo Didactic due to malicious intent or gross negligence.
Preface

Festo Didactic's training system for automation and technology is geared towards various educational backgrounds and vocational requirements. The training system is therefore broken down as follows:

- Technology-oriented training packages
- Mechatronics and factory automation
- Process automation and control technology
- Robotino® – training and research with mobile robots
- Hybrid learning factories

The technology packages deal with various technologies including pneumatics, electropneumatics, hydraulics, electrohydraulics, proportional hydraulics, programmable logic controllers, sensor technology, electrical engineering and electric drives.

The modular design of the training system allows for applications which go above and beyond the limitations of the individual packages; for example, PLC actuation of pneumatic, hydraulic and electric drives is possible.
All training packages have the same structure:

- Hardware
- Teachware
- Software
- Seminars

The hardware is comprised of industrial components and systems that are specially designed for training purposes.

The structure of the teachware corresponds to that of the hardware. It includes:

- Textbooks (with exercises and examples)
- Workbooks (with practical exercises, supplementary instructions and solutions)
- Exercise books (with practical exercises and supplementary explanations)
- Transparencies and videos (for dynamic instruction)

The teaching and learning media are available in several languages. They're intended for use in classroom instruction, but are also suitable for self-study.

Where software is concerned, computer training programs, as well as simulation, visualisation, project engineering, design engineering and programming software, are made available.

A wide range of seminar offerings covering the contents of the training packages round off the programme for training and vocational education.

If you have any suggestions or feedback about this manual,

please send us an e-mail at: did@de.festo.com

The authors and Festo Didactic look forward to your comments.
Introduction

This workbook is part of the training system for automation and technology from Festo Didactic GmbH & Co. KG. The system provides a solid basis for practice-oriented training and vocational education. Training package TP 1421 deals with the subject of Basic Principles of Servo Motor Drive Technology.

Special emphasis is placed on the design, function, connection, fields of application and control of a servo motor system on the basis of the requirements for the respective application.

Prerequisites for setting up the components are a permanent workstation equipped with a Festo Didactic slotted profile plate, a short-circuit-proof power supply unit with an output voltage of 24 V DC, and a short-circuit-proof power supply unit of 230 V AC.

The circuits for exercises 1 to 5 are constructed using the TP 1421 equipment set. For exercise 6, you also need an I/O simulation box and an I/O SysLink cable. These two components are not included in the equipment set.

Technical data for the individual components are also available (sensors, drives, motors, motor controllers, etc.).
Work and safety instructions

General
• Trainees should only work with the circuits under the supervision of a trainer.
• Observe specifications included in the technical data for the individual components and in particular all
  safety instructions!
• Faults which may impair safety must not be generated in the training environment and must be
  eliminated immediately.

Mechanical setup
• Mount all the components securely onto the slotted profile plate.
• Adhere to the instructions regarding positioning of the components.

Electrical setup
• The servo motor controller works with a supply voltage of 95 – 255 V AC. The servo motor controller
  must be connected to the power supply network in such a way that it can be separated from the network
  with appropriate isolation means (e.g. master switch, contactor, circuit breaker).
• Use only extra-low voltages, maximum 24 V DC, in control circuits.
• Electrical connections must only be established and interrupted in the absence of voltage!
• Only use connecting cables with safety plugs for electrical connections.
• Only pull the safety plugs when disconnecting the connecting cables – never pull the cable.

Mounting technology
The mounting boards for the components are equipped with mounting variants A, B or C:
• Variant A, snap-in system
  Lightweight components that not subject to loads (e.g. directional control valves, sensors).
  Simply clip the components into the slots on the slotted profile plate. Release the components by
  turning the blue lever.
• Variant B, bolt system
  Components subject to medium loads (e.g. pneumatic cylinders). These components are clamped to the
  slotted profile plate with T-head bolts. The blue knurled nut is used for clamping and loosening.
• Variant C, screw system
  For components that will be subject to heavy loads and that will rarely need to be removed from the
  slotted profile plate (e.g. on-off valve with filter regulator). The components are fastened with socket
  head screws and T-head nuts.
Training package for Basic Principles of Servo Motor Drive Technology (TP 1421)

Training package TP 1421 consists of a number of individual training materials. This package is about servo motors. Individual components from training package TP 1421 can also be included in other packages.

Important components of TP 1421

- Permanent workstation with Festo Didactic slotted profile plate
- Equipment sets or individual components (e.g. sensors, drives, motors, motor controllers)

Media

The teachware for training package TP 1421 consists of a workbook. This workbook contains the worksheets for each of the 6 exercises, the solutions to each individual worksheet and a CD-ROM. A set of ready-to-use exercises and worksheets is included for each exercise.

Technical data for the hardware components are made available with the training package and on the CD-ROM.

The Festo Configuration Tool (FCT) software is available for training package TP 1421. The FCT software configures the required functions of the electric drives. The drive function is implemented through the controller-motor-axis function chain. The software adjusts these components in relation to each other.

You will find further training materials in our catalogues and on the Internet. The training system for automation and technology is continuously updated and expanded. Transparency sets, videos, CD-ROMs, DVDs and training programmes as well as additional teachware are offered in several languages.
Training objectives

- **Servo motors**

- Become familiar with the safe design or assembly of a servo motor system
- Become familiar with the basic principles of connection technology and circuit technology for the components used
- Become familiar with the safe and correct way of commissioning a servo motor system
- Become familiar with the basic principles of configuration and parameterisation of a servo motor system using the Festo Configuration Tool (FCT)
- Be able to set and regulate the speed of a servo motor system
- Become familiar with the options for setting different acceleration and braking deceleration speeds using FCT
- Become familiar with the basic principles of configuring and recording measurement data using FCT
- Be able to carry out homing in a servo motor system
- Be able to set positions and position records and select positions
- Be able to control the positioning procedures in a servo motor system using sequence control
- Be able to check position records using FCT in a test cycle
- Become familiar with the various operating modes of a motor controller
- Be able to create and control a travel program with position record linking
- Be able to teach-in positions
### Allocation of training objectives and exercises

<table>
<thead>
<tr>
<th>Training objective</th>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Become familiar with the safe design or assembly of a servo motor system</td>
<td>•</td>
</tr>
<tr>
<td>Become familiar with the basic principles of connection technology and circuit technology of the components used</td>
<td>•</td>
</tr>
<tr>
<td>Become familiar with the safe and correct way of commissioning a servo motor system</td>
<td>•</td>
</tr>
<tr>
<td>Become familiar with the basic principles of configuration and parameterisation of a servo motor system using the Festo Configuration Tool (FCT).</td>
<td>•</td>
</tr>
<tr>
<td>Be able to set and regulate the speed of a servo motor system</td>
<td>•</td>
</tr>
<tr>
<td>Become familiar with the options for setting different acceleration and braking deceleration speeds using FCT</td>
<td>•</td>
</tr>
<tr>
<td>Become familiar with the basic principles of configuring and recording measurement data using FCT</td>
<td>•</td>
</tr>
<tr>
<td>Be able to carry out homing in a servo motor system</td>
<td>•</td>
</tr>
<tr>
<td>Be able to set positions and position records and select positions</td>
<td>•</td>
</tr>
<tr>
<td>Be able to control the positioning procedures in a servo motor system using sequence control</td>
<td>•</td>
</tr>
<tr>
<td>Be able to check position records using FCT in a test cycle</td>
<td>•</td>
</tr>
<tr>
<td>Become familiar with the various operating modes of a motor controller</td>
<td>•</td>
</tr>
<tr>
<td>Be able to create and control a travel program with position record linking.</td>
<td>•</td>
</tr>
<tr>
<td>Be able to teach-in positions.</td>
<td>•</td>
</tr>
</tbody>
</table>

**Note**

For exercise 6, you also need an I/O simulation box and an I/O SysLink cable. These two components are not included in the equipment set.
Equipment set for Basic Principles of Servo Motor Drive Technology (TP 1421)

The equipment set for Basic Principles of Servo Motor Drive Technology (TP 1421) teaches participants about the basic principles and use of servo motors. It contains all the components required to work through the specified learning objectives and can be supplemented with other equipment sets as desired.

A slotted assembly board, a 24 V DC power supply unit and a 230 V AC power supply unit are also required in order to set up functional circuits.

<table>
<thead>
<tr>
<th>Component</th>
<th>Order no.</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servo motor controller CMMS-AS-... (incl. interface cable)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Servo motor EMMS-AS-55-... (incl. connecting cables)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Rotary drive</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Proximity sensor, inductive, M8</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Connecting cable sensor</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Festo Configuration Tool software</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

To carry out exercise 6, you will also need the following components.

<table>
<thead>
<tr>
<th>Component</th>
<th>Order no.</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O simulation box (optional)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I/O SysLink cable (optional)</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Allocation of components and exercises

<table>
<thead>
<tr>
<th>Component</th>
<th>Exercise 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servo position controller CMMS-AS-...</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Servo motor EMMS-AS-55-...</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rotary drive</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inductive proximity sensor M8</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Connecting cable sensor</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Festo Configuration Tool software</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>I/O simulation box</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I/O SysLink cable</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 V DC power supply unit</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Power supply unit 230 V AC</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Notes for the teacher/trainer

Learning objectives
The basic learning objective of this workbook is to become familiar with servo motors and how to set up a servo motor system. The combination of both theory and practice ensures faster progress and longer-lasting learning. The more specific learning objectives are documented in the matrix. Concrete, individual learning objectives are assigned to each exercise.

Required time
The time required for working through the exercises depends on the learner’s previous knowledge of the subject matter. For apprentices in the field of metal or electrical engineering this is approx. 1 week. For a skilled worker it is approx. 2 days.

Equipment set components
The exercise book and equipment set match each other. You only need the components of equipment set TP 1421 for exercises 1 to 5. For exercise 6, you also need an I/O simulation box and an I/O SysLink cable. These two components are not included in the equipment set.

Each exercise can be constructed on a slotted mounting frame or slotted profile plate with a width of at least 350 mm.

Designations in the solution sheets
Solutions and supplements in graphics or diagrams appear in red.

Designations in the worksheets
Texts which require completion are identified with a grid or grey table cells. Graphics which require completion include a grid.

Solutions
The solutions specified in this workbook are the result of test measurements. The results of your measurements can deviate from these data.
Learning topics
The following table contains an overview of the learning topics offered by educational institutions on the training subject "Sensors for Object Sensing".

<table>
<thead>
<tr>
<th>Vocation</th>
<th>Learning topic</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics engineer for automation technology</td>
<td>1</td>
<td>Analysing electrical engineering systems and testing functions</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Analysing and adapting control systems</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Analysing systems and testing their safety</td>
</tr>
<tr>
<td>Mechatronics technician</td>
<td>3</td>
<td>Installation of electrical equipment, taking into account technical safety aspects</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Examination of the flow of energy and information in electrical, pneumatic and hydraulic assemblies</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Implementation of mechatronic subsystems</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Commissioning, troubleshooting and repair</td>
</tr>
<tr>
<td>Industrial technician</td>
<td>10</td>
<td>Installing and commissioning technical systems</td>
</tr>
</tbody>
</table>

Structure of exercises

All 6 exercises have the same structure and are broken down into:
- Title
- Learning objectives
- Problem description
- Positional sketch
- Project assignment
- Work aids
- Worksheets
CD-ROM contents

The workbook is included on the CD-ROM as a PDF file. The CD-ROM also provides you with additional media.

The CD-ROM contains the following folders:
- Operating instructions
- Technical data
- Product information
- Software tools

Operating instructions
Operating instructions for various components in the training package are available. These instructions are helpful when using and commissioning the components.

Technical data
The technical data for the components included in the training package are available as PDF files.

Product information
The manufacturer’s product information is provided for selected components. The representations and descriptions of the components in this format are intended to demonstrate how they are presented in an industrial catalogue. Additional information regarding the components is also included.

Software tools
The software tools to work on the exercises are provided on the CD-ROM.

Note
Up-to-date information and additional software tools please find at the address:
www.festo.com > Support and Downloads > Software > Electrical drives.
Exercise 1
Constructing a servo motor system

Learning objectives
After completing this exercise:
- You will be familiar with the safe design or assembly of a servo motor system
- You will be familiar with the basic principles of connection technology and circuit technology of the components used

Problem description
A servo motor system is creating using individual components. The motor controller, servo motor, rotary drive, signal input and proximity sensor must be correctly connected or linked in order to obtain a reliable entire system.

Positional sketch
![Servo motor system]
Project assignment
1. Describe the design and function of the components used.
2. Connect the modules to form a complete, reliable system.

Work aids
- Technical data
- Operating instructions

Warning
The electric power supply must not be switched on until all connections have been connected and tested. The power supply must be switched off again once the exercise has been completed and before the components are removed.
**Function description**

- Complete the following table. Use the required data from the data sheet for the inductive proximity sensor.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working range/rated operating distance</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>Repetition accuracy</td>
<td>0.07 mm</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>10 – 30 V DC</td>
</tr>
<tr>
<td>Switching output</td>
<td>N.C., normally closed</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>5000 Hz</td>
</tr>
</tbody>
</table>

- Complete the following table. Use the required data from the data sheet for the servo motor.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal voltage</td>
<td>360 V DC</td>
</tr>
<tr>
<td>Nominal torque</td>
<td>0.68 Nm</td>
</tr>
<tr>
<td>Nominal speed</td>
<td>6600 rpm</td>
</tr>
<tr>
<td>Torque at standstill</td>
<td>0.98 Nm</td>
</tr>
<tr>
<td>Motor constant</td>
<td>0.558 Nm / A</td>
</tr>
</tbody>
</table>

- Complete the following table. Use the required data from the data sheet for the motor controller.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage [X9]</td>
<td>1-phase/ 95 – 255 VAC</td>
</tr>
<tr>
<td>Nominal output current [X9]</td>
<td>3 A</td>
</tr>
<tr>
<td>Output voltage [X6]</td>
<td>320 V</td>
</tr>
<tr>
<td>Number of digital switching outputs [X1]</td>
<td>4</td>
</tr>
<tr>
<td>Signal level of analogue inputs [X1]</td>
<td>-10 – +10 V</td>
</tr>
</tbody>
</table>
## Construction of the complete system

1. Connect the motor
   - Make sure that the power supply is switched off.
     * Power supply master switch is in the position OFF/AUS
     * 24 V power supply is switched off
   - Fasten the motor to the rotary drive using the locking screws and mount the module onto the slotted profile plate.
   - Connect the motor cable and the shaft encoder cable to the controller unit.
     * Plug the motor cable into the socket [X6] of the controller unit and tighten it.
     * Insert the sub-D plug connector into socket [X2] of the controller and tighten the locking screws.
   - Mount the proximity sensors in the sensor retainer of the rotary drive.
   - Connect the proximity sensors via sensor cables to the controller unit (\text{D}_{\text{in}}^{6}\text{-Limit0}/\text{D}_{\text{in}}^{7}\text{-Limit1}).

### Note
End-position sensing can take place with sensors or using signal switches.

2. Connect the motor controller
   - Connect the controller unit and the main power supply using 4 mm safety plug connectors.
   - Connect the controller unit to the 24 V power supply unit using 4 mm safety plug connectors.

3. Connect the PC
   - Connect the controller unit to the PC with the serial interface cable.
     * Insert the sub-D plug connector of the serial cable into socket [X5] RS232/COM of the motor controller and tighten the locking screws.

4. Check readiness for operation
   - Make sure that the "Controller Enable" switch is switched off.
   - Check all plug connectors once again.
   - Switch on the power supply of the equipment. The READY LED on the front of the motor controller should now light up.

5. Switch off system and power supply
- Check the switches of the signal input.
  - Signal switches “Limit0” and “Limit1” are in position OFF/AUS (switch upwards)
  - Potentiometer switch A₁₅₀ is in position 0
  - "Record Selection" selector switch is in position 0
  - "Analogue/Digital" selector switch is in digital position (switch downwards)
  - "Internal/External" selector switch is in internal position (switch upwards)
- Switch off the 24 V DC power supply unit and the power supply master switch (230 V AC).

**Note**
Through the sub-D socket [X1], external analogue signals can be recorded or output by the controller. Analogue setpoint specification by hand is done using the potentiometer switch A₁₅₀. Make sure that the "Internal/External" selector switch is in the "Internal" position (switch upwards)!

If the READY LED is not lit, there is a malfunction. If the segment display shows a number sequence, there is an error message. You must rectify the cause of the message. In this case, read the operating mode and error messages in chapter 8.2 in the manual "Motor Controller CMMSAS-...".