Motors and Controllers
With Mechatronic Motion Solutions, Festo offers you a system that is unique in the world and comprises components, modules, systems and software. It combines all types of pneumatic, servo-pneumatic and (electro-)mechanical automation movements, depending on your application. Irrespective of the control environment you use, Mechatronic Motion Solutions provides the appropriate interfaces.

Mechatronic
Guarantees mechanical and electrical compatibility and combination at all levels. All pneumatic and electric drives are equipped with the relevant mechanical, power supply and data interfaces. This ensures that different technologies can be combined in one system and makes setup of complex handling and positioning systems safe and easy.

Motion
Stands for the comprehensive, multi-dimensional portfolio of linear and rotary drives as well as a large variety of mechanical and vacuum grippers. Provides general and specific benefits, such as high speed, precision, etc.

Solutions
Represents Festo’s many years of experience in the handling system sector, across all industries and continents. This includes first-class expertise in developing components to competence in sophisticated systems, from pre-designed and calculated components and sub-systems to complete systems. The logical answer to any demand for pre-installed and customised systems and solutions.
Motors and motor controllers

The modular handling system naturally includes a large variety of harmonised motors and controllers. With servo or stepper motors and the unique ServoLite functionality. Ideally matched to all electric drives; can also be combined with external drives.

Servo technology for high dynamic response and precision: highly functional motor controller CMMP-AS, standard controller CMMS-AS and servo motor EMMS-AS.

→ For more information, see page 6.

Stepper motor technology for safe and low-cost solutions for standard tasks: motor controller CMMS-ST and stepper motor EMMS-ST with ServoLite operating mode.

→ For more information, see page 8.

All-in-one solution: intelligent drive motor MTR-DCI with integrated controller for on-site installation.

→ For more information, see page 10.

Field controllers in high protection class for specialised drives and solutions with integrated motor: SFC-DC for drives with integrated stepper motor and SFC-LAC for linear motor drives.

→ For more information, see page 12.

Multi-axis controllers

Designed for controlling multi-axis systems with different control concepts, such as 3 D, 2.5 D and point-to-point. Include easy integration in existing control concepts and control systems thanks to fieldbus communication and various input and output modules.

→ For more information, see page 17.
# Mechatronic Motion Solutions: an overview of the world of electric drives

## Management level

### Control level

- **Controller**
  - PLC (ABB, Allen-Bradley, Rockwell, Siemens etc.)
  - Integrated controller CECX
  - Integrated controller FED-CEC

### Motor Controller

- Servo motor controller CMMP-AS
- Servo motor controller CMMS-AS
- Stepper motor controller CMMS-ST
- Servo motors EMMS-AS
- Stepper motors EMMS-ST

## Field level

### Control

### Drives

### Front Unit

## Pneumatic

### Servo-pneumatic

### Electronic

### Gantry axes

- EGC
- DGE
- DGE-ZR-RF
- EGSK/EGSP

## Grippers

- Electric grippers
- Positioning grippers
- Parallel grippers
- Three-jaw grippers
- Angle and radial grippers
- Micro grippers
- Swivel/gripper unit
Festooning and Positioning Profile

CoDeSys provided by Festo

FST 4
Festo Software Tool

FCT
Festo Configuration Tool

PositioningDrives
Design and dimensioning software for electric drives

FHPP
Festo Handling and Positioning Profile

Robotic controller
CMXR

Axis interface
CPX-CMXX

Motor controller
SFC-LAC

Drive motor
MTR-DCI

SFC-DC

Cantilever axes
EGSA

DGEA

DNCE

Handling axis
HME with linear motor

Mini slide
SLTE with DC motor

Vacuum
Vacuum grippers

Vacuum generators

Rotary drives
Electric

Pneumatic

Camera systems
Diagnostics and commissioning
Type, position and rotary orientation recognition

EthernetFieldbus AS-Interface
Servo motors and servo motor controllers

**Servo motor controller CMMP-AS**
The range of servo motor controllers is a highly functional solution for dynamic motion. Ideally suited for the electronic control of cam discs.

**Servo motor controller CMMS-AS**
The servo motor controller CMMS-AS is particularly well-suited for standard applications and positioning tasks with I/O and fieldbus connection.

**Two controller versions – one philosophy**
- The software tools provided by Festo offer an integral concept from commissioning to programming to parameterisation
- Uniform and simple handling
- Integrated secure holding with restart locking for safety-related applications
- Multi-firmware strategy makes it possible to use individually defined firmware versions

**Servo motor EMMS-AS**
One servo motor for two controller types. As a permanently energised, brushless servo motor with eight torque ranges, this motor is designed for dynamic positioning tasks.

- Single-turn shaft encoder (standard), multi-turn shaft encoder (optional)
- Motor housing and power/generator connection with protection class IP65
- Motor shaft bearing:
  - Standard IP54
  - Optional with additional rotary shaft seal IP65
- Matching programme of planetary gear units
### Technical data and functions

**CMMS-AS**
- Primary voltage: 100-230 V AC
- Motor current, single-phase: 4 A
- 64 integrated positioning records
- SD card for parameters and firmware
- Automatic motor brake
- External braking resistor (optional)
- Jerk-free positioning
- Endless positioning

**CMMP-AS**
- As the CMMS-AS, but:
  - Motor current, single-phase: 2.5 and 5 A
  - Motor current, three-phase: 5 and 10 A
  - 256 integrated positioning records
  - High speed measurement
  - Electronic cam disk
  - Flexible software limit switch

### Controller benchmarks

<table>
<thead>
<tr>
<th>Motor controllers for motor type</th>
<th>CMMS-AS Servo motor</th>
<th>CMMP-AS Servo motor</th>
<th>CMMS-ST Stepper motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque at standstill [Nm]</td>
<td>~4.7</td>
<td>~25</td>
<td>~8.5</td>
</tr>
<tr>
<td>Peak torque [Nm]</td>
<td>~9.2</td>
<td>~48</td>
<td>~8.5</td>
</tr>
<tr>
<td>Rotational speed [1/min]</td>
<td>~10000</td>
<td>~10000</td>
<td>~3000</td>
</tr>
<tr>
<td>Positioning records</td>
<td>63</td>
<td>255</td>
<td>63</td>
</tr>
<tr>
<td>Measuring system</td>
<td>Incremental/absolute</td>
<td>Incremental/absolute</td>
<td>Incremental/absolute</td>
</tr>
<tr>
<td>Extended I/O interface</td>
<td>4 working modes</td>
<td>Can be configured flexibly</td>
<td>4 working modes</td>
</tr>
<tr>
<td>Notification of remaining distance</td>
<td>1 for n</td>
<td>Separately for all positions</td>
<td>1 for n</td>
</tr>
<tr>
<td>Torque reduction</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Set linking</td>
<td>Linear</td>
<td>With branching</td>
<td>Linear</td>
</tr>
<tr>
<td>Safe stop</td>
<td>To EN 954-1 Cat. 3</td>
<td>To EN 954-1 Cat. 3</td>
<td>–</td>
</tr>
</tbody>
</table>

### The performance ranges of the motors in conjunction with the Festo controllers

![Graph showing performance ranges](image)

- EMMS-AS + CMMP-AS
- EMMS-AS + CMMS-AS
- EMMS-ST + CMMS-ST
Stepper motors and stepper motor controllers

Stepper motor controller
CMMS-ST
Stepper motor technology in a genuine plug and work solution package: the single-axis position controller CMMS-ST combined with the stepper motor EMMS-ST for single and multi-axis handling with moveable masses of up to 20 kg.

The ServoLite operating mode offers a fully-fledged closed-loop servo system with the highest degree of operational reliability and fast dynamic response by using the maximum motor characteristic curve. This sets it apart from conventional controllers of this type. Alternatively, the CMMS-ST can also function as an inexpensive open-loop system with stepper motors without encoder. The extensive range of functions and the optimum price-performance ratio provide further advantages.

The integrated FCT platform software and the standardised FHPP data profile ensure problem-free commissioning, programming and parameterisation.

Stepper motor EMMS-ST
- Stepper motor series using two-phase hybrid technology for a long service life
- 6 torque ranges
- Encoder for ServoLite function (optional)
- Motor brake optional
- Motor housing and plug connection in protection class IP65
- Motor shaft bearing IP54
- Suitable planetary gearing
- Harmonised and compatible with all electric axes from Festo
Technical data and functions

CMMS-ST
- Primary voltage: 24 ... 75 V DC
- Motor current: 8 A (peak 12 A)
- Step resolution: full steps up to 4,000 steps/revolution
- 64 integrated positioning records, e.g. acceleration ramps
- SD card for parameters and firmware
- Automatic motor brake
- External braking resistor (optional)
- Jerk-free positioning
- Endless positioning
- Digital inputs and outputs protected against short circuit, overload and reverse voltage

Controller benchmarks

<table>
<thead>
<tr>
<th>Motor controllers for motor type</th>
<th>CMMS-ST Servo motor</th>
<th>CMMS-AS Servo motor</th>
<th>CMMP-AS Servomotor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque at standstill [Nm]</td>
<td>~8.5</td>
<td>~6.7</td>
<td>~7.5</td>
</tr>
<tr>
<td>Peak torque [Nm]</td>
<td>~8.5</td>
<td>~9.2</td>
<td>~8.5</td>
</tr>
<tr>
<td>Rotational speed [1/min]</td>
<td>~3000</td>
<td>~10000</td>
<td>~10000</td>
</tr>
<tr>
<td>Positioning records</td>
<td>63</td>
<td>63</td>
<td>55</td>
</tr>
<tr>
<td>Measuring system</td>
<td>Incremental</td>
<td>Inkremental/absolute</td>
<td>Inkremental/absolute</td>
</tr>
<tr>
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<td>4 working modes</td>
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</tr>
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<td>1 for n</td>
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</tr>
<tr>
<td>Set linking</td>
<td>Linear</td>
<td>Linear</td>
<td>Linear with branching</td>
</tr>
<tr>
<td>Safe stop</td>
<td>–</td>
<td>To EN 954-1 Cat. 3</td>
<td>To EN 954-1 Cat. 3</td>
</tr>
</tbody>
</table>
Intelligent drive motor MTR-DCI

The innovative drive motor with its wide torque range is ideally suited for positioning tasks. All in one, it includes all the necessary components: motor, gear unit, motor controller and power electronics.

Its integrated power electronics and controller remove the need for long motor cables, thus improving the electromagnetic compatibility. Additional, integrated monitoring functions ensure optimised reliability and system availability and simplify the fault finding process.

Another convincing feature of the MTR-DCI is the fact that it requires minimal wiring due to the integration of the controller; only one voltage source and only one fieldbus connection or multipin plug are required. The entire commissioning process is performed on-site or from a PC using a simple teach-in function, thanks to an optional LC display and clear menus, and is supported by the FCT (Festo Configuration Tool) software.

Functions
- Compact design with integrated display
- Complete unit with integrated gear unit and position controller
- Profile is insensitive to dirt due to smooth surfaces
- Closed-loop operation
- DC motor with planetary gear unit and encoder
- Activation via I/O or fieldbus

CANopen

DeviceNet

- Protection class IP54

Positioning functionality
- 16 positioning records (including homing)
- Constant acceleration and braking
- Homing mode:
  - Left or right until the switching signal
  - Left or right until the mechanical stop (preferable)
- Position control

Protective functions
- Temperature monitoring
- Current monitoring
- Voltage failure detection
- Following error monitoring
- Software end position detection
## Technical data

### Electrical data – Motor

<table>
<thead>
<tr>
<th>Size</th>
<th>32</th>
<th>42</th>
<th>52</th>
<th>62</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal voltage [V DC]</td>
<td>24 ± 10 %</td>
<td></td>
<td></td>
<td>48 - 10 %/+5 %</td>
</tr>
<tr>
<td>Nominal current (motor) [A]</td>
<td>0.73</td>
<td>2</td>
<td>5</td>
<td>6.19</td>
</tr>
<tr>
<td>Peak current [A]</td>
<td>2.1</td>
<td>3.8</td>
<td>7.7</td>
<td>20</td>
</tr>
<tr>
<td>Gear ratio G7</td>
<td>6.75 (7:1); 1-stage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gear ratio G14</td>
<td>13.73 (14:1); 2-stage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gear ratio G22</td>
<td>22.21 (22:1); 2-stage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Mechanical data – Motor

<table>
<thead>
<tr>
<th>Size</th>
<th>32</th>
<th>42</th>
<th>52</th>
<th>62</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear ratio</td>
<td>6.7</td>
<td>G14</td>
<td>6.7</td>
<td>G14</td>
</tr>
<tr>
<td>Gearing output speed [1/min]</td>
<td>481</td>
<td>237</td>
<td>444</td>
<td>218</td>
</tr>
<tr>
<td>Gearing output torque [Nm]</td>
<td>0.15</td>
<td>0.29</td>
<td>0.59</td>
<td>1.13</td>
</tr>
<tr>
<td>Radial shaft load [N]</td>
<td>40</td>
<td>70</td>
<td>160</td>
<td>230</td>
</tr>
<tr>
<td>Axial shaft load [N]</td>
<td>10</td>
<td>20</td>
<td>50</td>
<td>80</td>
</tr>
</tbody>
</table>
Single-field controllers

Motor controller SFC-DC
Simple selection and commissioning. The SFC-DC concept embraces the easy entry of positioning records at the controller via the human-machine interface or via the computer-aided Festo Configuration Tool. Perfect as a ready-to-install Festo plug and work® solution in combination with the electric gripper HGPLE or electric slide SLTE.

Positioning controller SFC-LAC
Similar to the SFC-DC, the SFC-LAC offers the same functions for the handling axis HME as a pre-assembled solution.

Simple configuration
Both single-field controllers are very easy to configure and commission using FCT software for parameterisation and commissioning: just enter the parameters and positioning records, and you’re ready to go.

- Basic parameterisation of the mechanical system, the position controller and the positioning records
- Positioning run
- Teach-in operation
- Homing and commissioning
- Diagnostic function

Advantages
- Thanks to the protection class IP54, the SFC can be mounted close by, either using central supports or an H-rail
- Only one cable needed
- Motor controller SFC available with or without control panel
- Easy activation via:
  - I/O interface
  - Profinet
  - CANopen
  - DeviceNet
## Technical data

<table>
<thead>
<tr>
<th>Electrical data</th>
<th>SFC-DC</th>
<th>SFC-LAC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rating output</td>
<td>[W]</td>
<td>75</td>
</tr>
<tr>
<td><strong>Load supply</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal voltage</td>
<td>[V DC]</td>
<td>24 ± 10 %</td>
</tr>
<tr>
<td>Nominal current</td>
<td>[A]</td>
<td>3</td>
</tr>
<tr>
<td>Peak current</td>
<td>[A]</td>
<td>5</td>
</tr>
<tr>
<td><strong>Logic supply</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal voltage</td>
<td>[V DC]</td>
<td>24 ± 10 %</td>
</tr>
<tr>
<td>Nominal current</td>
<td>[A]</td>
<td>0.1</td>
</tr>
<tr>
<td>Peak current</td>
<td>[A]</td>
<td>0.8</td>
</tr>
<tr>
<td>Max. current per output (digital logic outputs)</td>
<td>[A]</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Single-field controllers

SFC-DC for controlling the electric mini slide SLTE
The advantage: only one cable connects the SLTE and the SFC-DC.

Electro-mechanical mini slide SLTE
• Rigid precision guide
• Freely positionable
• Fast positioning times
• Sensors can be integrated
• Gentle starting and stopping
• Effective loads of up to 4 kg
• Constant travel speeds of 2 ... 200 mm/s

Electrical mini slide

<table>
<thead>
<tr>
<th>Electrical mini slide</th>
<th>SLTE-10</th>
<th>SLTE-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guide</td>
<td>Roller bearing guide</td>
<td>Roller bearing guide</td>
</tr>
<tr>
<td>Stroke [mm]</td>
<td>50/80</td>
<td>50/80/100/150</td>
</tr>
<tr>
<td>Max. speed [m/s]</td>
<td>0.17</td>
<td>0.21</td>
</tr>
<tr>
<td>Min. speed [m/s]</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Repetition accuracy [mm]</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Max. effective load (horizontal at V_{max}) [kg]</td>
<td>1.5</td>
<td>4</td>
</tr>
<tr>
<td>Max. effective load (vertical at V_{max}) [kg]</td>
<td>0.35</td>
<td>0.7</td>
</tr>
<tr>
<td>Max. torque load M_x [Nm]</td>
<td>4.3</td>
<td>12.6</td>
</tr>
<tr>
<td>Max. torque load M_y [Nm]</td>
<td>4.3</td>
<td>12.6</td>
</tr>
<tr>
<td>Max. torque load M_z [Nm]</td>
<td>1.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

SFC-DC for controlling the electric gripper HGPLE
The advantage: only one cable connects the HGPLE and the SFC-DC.

Electric T-slot parallel gripper HGPLE
• Free, speed-controlled selection of the gripper positions with long stroke
• Perfect for soft or highly sensitive workpieces thanks to tactile gripping option
• Alternative: reliable gripping of large and heavy workpieces
• Sturdy design: T-slot for very high torque resistance, with high accuracy
• At least 5 million strokes guaranteed
• Reduced cycle times thanks to “holding positions”: the gripper fingers park shortly before the workpiece
• Short opening and closing times of 0.6 s with a total stroke of 40 mm per gripper jaw

Electric gripper

<table>
<thead>
<tr>
<th>Electric gripper</th>
<th>HGPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>25</td>
</tr>
<tr>
<td>Max. total gripping force [N]</td>
<td>600</td>
</tr>
<tr>
<td>Max. stroke per gripper jaw [mm]</td>
<td>40</td>
</tr>
<tr>
<td>Max. speed [mm/s]</td>
<td>65</td>
</tr>
<tr>
<td>Max. acceleration [mm/s²]</td>
<td>500</td>
</tr>
<tr>
<td>Max. permissible force F_x [N]</td>
<td>1500</td>
</tr>
<tr>
<td>Max. permissible torque M_x [Nm]</td>
<td>100</td>
</tr>
<tr>
<td>Max. permissible torque M_y [Nm]</td>
<td>60</td>
</tr>
<tr>
<td>Max. permissible torque M_z [Nm]</td>
<td>70</td>
</tr>
</tbody>
</table>
SFC-LAC for controlling the handling axis HME

The advantage: only one cable connects the HME and the SFC-LAC.

Handling axis HME

• With integrated linear motor, displacement encoder, guide and position controller
• Ready-to-install system for greater flexibility, precision and dynamic response
• Maximum ease of movement through free choice of position, acceleration, speed and force

Additional features:

• Basic parameterisation of the mechanical system, the position controller and the positioning records
• Teach-in mode
• Homing and limit switch
• Diagnostic function
• Contactless displacement encoder with sensor head and integrated measuring band

<table>
<thead>
<tr>
<th>Electric cantilever axes</th>
<th>HME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>16/25</td>
</tr>
<tr>
<td>Drive</td>
<td>Linear direct drive</td>
</tr>
<tr>
<td>Guide</td>
<td>Recirculating ball bearing guide</td>
</tr>
<tr>
<td>Max. stroke [mm]</td>
<td>400</td>
</tr>
<tr>
<td>Max. speed [m/s]</td>
<td>3</td>
</tr>
<tr>
<td>Repetition accuracy [mm]</td>
<td>±0.015</td>
</tr>
<tr>
<td>Max. effective load (horizontal) [kg]</td>
<td>25 (with 100 mm stroke)</td>
</tr>
<tr>
<td>Max. effective load (vertical) [kg]</td>
<td>–</td>
</tr>
<tr>
<td>Max. force F, [N]</td>
<td>257 (peak feed force)</td>
</tr>
<tr>
<td>Max. torque load M_x, [Nm]</td>
<td>–</td>
</tr>
<tr>
<td>Max. torque load M_y, [Nm]</td>
<td>–</td>
</tr>
<tr>
<td>Max. torque load M_z, [Nm]</td>
<td>–</td>
</tr>
<tr>
<td>Options</td>
<td>–</td>
</tr>
</tbody>
</table>
Electric drives

Suitable for the Festo motors EMMS-ST, EMMS-AS, MTR-DCI *

Gantry axes
- Electric toothed belt axes and spindle axes EGC
- Electric axis DGE
- Electric toothed belt axis DGE-ZR-RF

Cantilever axes
- Electric axes EGSK/EGSP
- Spindle axes DMES
- Cantilever axis with spindle EGSA
- Cantilever axis with toothed belt drive DGEA
- Electric piston rod cylinder DNCE

Rotary drive module
- Rotary drive module ERMB

*Also suitable for attaching third-party motors

Note:
For matching gear units, visit www.festo.com
Multi-axis control systems

Robotic control CMXR
• Real 3D functionality for free path control of up to six axes, similar to a robotic functionality
• In its function as a control system for three main axes and three secondary axes, the CMXR is compatible with Cartesian and tripod kinematics

Handheld terminal CDSA
• When adapted to the robotic controller CMXR, the handheld terminal CDSA enables the CMXR to be programmed at the highest level
• Simple programming in the Festo Teach Language (FTL), operation and diagnostics, including teach-in function

Modular control CECX
• The modular control CECX extends the Festo range of control systems, adding fieldbus master functions and electrical activation options to the upper segment.
• Two product designs: modular master control and motion controller

Integrated control system FED-CEC
• Space-saving control concept
• The processor module based on the CoDeSys software platform can be integrated in the Front End Display series 50 to 5000
• Display unit and control system in one housing
• Easy activation of electric drives

Multi-axis interface CPX-CMXX
• Perfect CPX module for uniform parameterisation and control of electric drives
• Designed for easy commissioning and integration of multi-axis systems into all commonly used control systems
Design, faster project planning, commissioning and operation

CAD hotline and design
• Standard designs from the mechatronic multi-axis modular system
• Simple modifications, e.g. adjustment of the strokes
• 3D models and 2D drawings
• Designs from the mechatronic multi-axis modular system
• Aluminium or steel structure

FCT software – Festo
Configuration Tool for commissioning
• All the drives in a system can be managed and archived in a common project
• Simple to use thanks to graphically supported parameter entry
• Universal mode of operation for all drives
• Work offline at your desk or online at the machine

FHPP – Festo Handling and Positioning Profile
The FHPP data profile, which is tailored to handling and positioning applications, permits the activation of Festo motor controllers, using a fieldbus interface, via standardised control and status bytes.

• Free access to all parameters – read and write
The PositioningDrives software tool prevents incorrect designs and energy waste thanks to the right choice of components. Designing drive mechanics, gear unit and motor separately increases safety factors, resulting in oversized electronic drive systems and wasted primary energy.

Toothed belt drives, spindle drives or direct drives, servo motors, stepper motors or DC motors, ball-bearing guides or plain-bearing guides – the plethora of different options to choose from presents the user with a major challenge: calculating the correct drive.

PositioningDrives calculates the ideal combination from the widely coordinated range of electric linear axes, motors, gear units, controllers and software after a few application data have been entered. By specifying various project parameters, the tool also calculates the characteristic load values for the selected drive quickly and reliably.

Typical program interfaces

Application parameters
Such as mounting position, load, stroke and accuracy. You also have the option of specifying the required process time and pre-selecting the drive technology.

Select the required solution package
For easy selection, these are sorted by motor and axis technology, component utilisation, cycle time or the package price.

Detailed results
The program also provides detailed results, such as motor characteristic curve, dynamic characteristic values, system data, product data and parts list. These results are saved as a file and can be used for ordering and machine documentation.