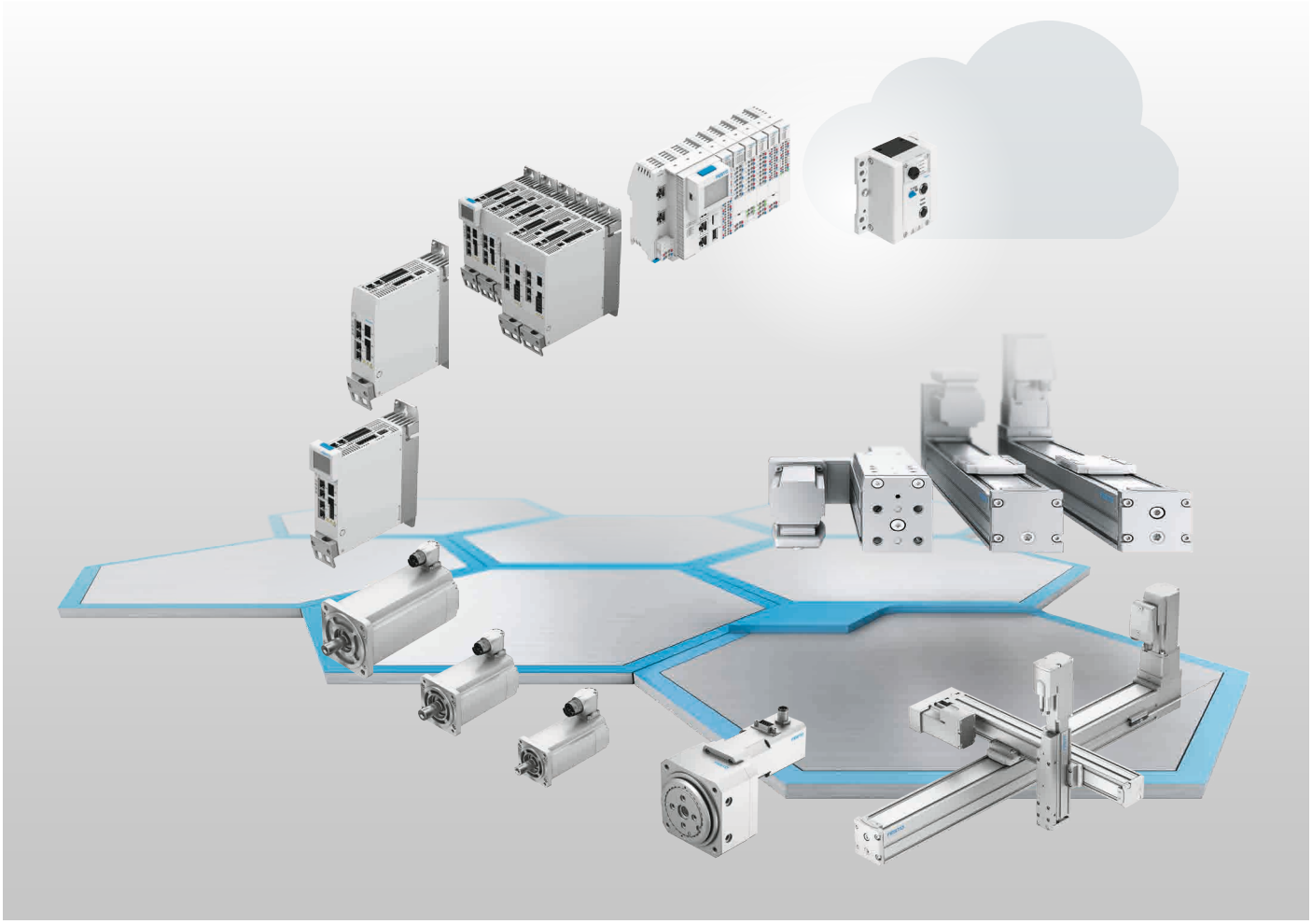
# White paper: Seamless connectivity in industrial automation



Large-scale changes in industrial automation are leading to new challenges and require new solutions and concepts. Digitalisation meets globalisation, flexibility meets standardisation, all while development and production times are getting ever shorter. Based on practical experience, Festo presents some challenges and their possible solutions here.

This white paper provides information on:

- Changes in industrial automation – what is the status quo and in which direction will production develop in the future
- Seamless connectivity – more than just the interfaces of individual components
- Hardware and software solutions – how they help to shorten time to market and make you faster and more flexible

# Executive summary

What is seamless connectivity?

Seamless connectivity is about taking into account all interfaces in industrial automation as well as their perfect interaction. Its goal is to ensure that mechanical and electrical interfaces as well as the intelligent interfaces of automation platforms are optimally coordinated with one another across the entire engineering process. It also needs to describe them and make them quick and easy to use for the customer. With this goal in mind, Festo considers automation architecture from the mechanical system to the motors, servo drives as well as the controllers (motion control) and right up to modern industrial cloud solutions.

> Seamless connectivity – i.e. industrial automation from the workpiece right up to the cloud for both hardware and software.

What are the benefits of seamless connectivity for industrial automation?

Seamless connectivity makes engineering processes faster and simpler, creating reliability from the outset and reducing the time and effort required. At the same time, automation concepts become more flexible and more efficient.

1 Seamlessly coordinated mechanical and electrical connectivity permits flexible adaptation to the requirements of the application and also provides possibilities for standardisation.
2 Intelligent connectivity enables flexible and modular control concepts and the direct connection of a servo drive to a variety of different controllers.
3 In line with the above, a uniform software platform guarantees seamless and reliable data across the entire development and production process, from layout and conceptualisation to design and from programming to commissioning.

# Industrial automation in flux – changes and challenges

## Networking with Industry 4.0

It is no secret that the latest technologies are rapidly changing the production environment. We are witnessing a new industrial revolution, one that is driven by dynamic trends and digital possibilities. New opportunities are arising both for machine builders and for machine and system operators.

Many of today's concepts are being or have already been overtaken by the 4th Industrial Revolution: business models, partnerships, customer interfaces, value chains and even the classic automation pyramid are being newly defined.

To achieve this, Industry 4.0 relies on networked, adaptive production with modular structures and hierarchies as well as on intelligent products with their embedded functions – known as cyber-physical systems. As a result, the classic machine architecture with its central control system as per the well-known automation pyramid is increasingly moving towards versatile automation subsystems. These are then decentrally and closely interlinked, communicate directly with one another and exchange data. Besides greater flexibility in the production process, this also leads to greater variation in machine concepts, particularly for the increased requirements of globalisation.

The increasingly networked components require a high level of compatibility and integrability on the part of all system participants. On the one hand, an unobstructed data exchange facilitates a smooth procedure but, on the other, all components need to be coordinated in the system in line with the application while at the same time perfectly matching one another.

> Seamlessly and digitally networked automation technology, including decentralised intelligence in components, generates production and status data in real time, allows virtual commissioning of a digital twin and enables communication from the supplier to the end user via open communication standards.

Networking with OPC UA: further processing "on premise" or in the cloud

## Interconnected and interacting in a system

One area that is developing rapidly and offering users improved efficiency is what is known as connectivity – networked and cooperative interaction and communication in a system. The term connectivity describes the virtually ideal ability of a component or a subsystem to be integrated in a higher-level structure, as well as the optimal coordination of components or participants with one another in the system.

When considering connectivity as a whole, including all automation components and all participants, we need to take the (intelligent) communication and control interface as well as the mechanical interface and the electrical interface into account. Viewing it as a whole means from the workpiece all the way up to the cloud for both hardware and software.

So far, no uniform standards have yet been developed that can be applied to all levels, not just for Industry 4.0 but for classic automation solutions too; it is mostly stand-alone solutions that are still used to handle subtasks, but which do not allow a seamless approach. This is particularly the case if the solution comprises different areas of automation, for example if linear mechanical systems and servo drive technology have to be combined quickly and easily with different control concepts.

This opens up many opportunities to increase efficiency and offers huge potential for improving the development process for machines and systems as well as for the products and subsystems themselves, right up to the commissioning of industrial systems.

> Networked production systems that have an extremely flexible uniform design stand for economical just-in-time production up to batch size 1, higher machine availability and greater process flexibility as well as the rapid adjustment of machine utilisation in a production network.

Seamlessly networked and flexible assembly lines for batch sizes from 10 to 10,000 pcs

# Seamless connectivity in automation technology

## What is connectivity?

Essentially, connectivity is the ability to connect and link up individual participants i.e. the interfaces. When transferred to industrial applications, machines and automation concepts, this means that individual components work together and are connected with one another in the system.

To be able to speak about seamless connectivity, the mechanical interface, the electrical interface and the intelligent interfaces need to be taken into account for all components. This not only applies to the hardware but also to the software in which the different interfaces are mapped.

When looking closely at a machine, it is clear that each automation component has its own interfaces that interact with others. With the correct design, combination and interaction of individual components, supported by suitable software, it will be possible to create concepts and applications that can handle as many complex tasks as necessary.

**The objective of seamless connectivity** is to make different interfaces as simple and easy to handle as possible, so that using them is more reliable and above all faster. This applies to the entire process, from the initial concept phase to the design all the way up to commissioning. Although it does not reduce the complexity of a machine, using it becomes easier and more reliable; while conceptualisation, operation, design and commissioning become faster. The machine builder and end user can then concentrate more effectively on their tasks in hand.

> Connectivity in automation technology must be regarded as a whole and for seamless solutions all interfaces – mechanical, electrical and intelligent – have to interact perfectly at all times. This applies to hardware and software, to specific productions and for digital twins across the entire process, from design and engineering to commissioning.

## Today's prevalent automation architectures at a glance

Probably the most commonly used automation hierarchy in machines and production systems is based on what is known as the classic automation pyramid. The individual products and automation components are assigned to individual levels in the pyramid. On every level, for each component group, the user or the machine builder will have to take into account the various different interfaces and nevertheless connect them with one another to attain seamless connectivity.

Details on the automation pyramid can be found on the pages that follow.

**Actuator level**

Right at the bottom are the electromechanical automation components, mostly linear mechanical components but also grippers and simple rotary drives. These are installed in the machine's working area and are mostly in direct contact with the workpiece, the product. This is moved and positioned with their help in line with the production process. Besides individual electromechanical axes, handling systems (Cartesian multi-axis systems), in part with complex mechanical systems, are also used.

The challenge for the engineer is to design the electromechanical system so that it corresponds to the requirements of the application in terms of dynamic response, load or precision and provides (safety) reserves. Such a system should not be oversized but still very durable.

To do this, the engineer needs among other things:

- Electronic design tools or datasheets with tables and diagrams for the design/ calculation and selection of components
- CAD models of all components and handling systems for integration into the machine. This applies to specific products and to digital twins
- Manuals, datasheets, assembly instructions, etc.
- Application data and motion data for simulation or calculation.

> Components can be separated into levels, but when it comes to interaction everything must fit. The design of the mechanical system for the automation of motion must match the configuration of the servo drive system. This electromechanical drive system now needs to be integrated optimally into the control environment. Software tools for design, configuration and commissioning play a key role here.

**Field level**

This is the level where servo drives are located. They control the corresponding motor for dynamic response, position or force and are connected, electrically and in terms of control technology, to a motion controller via a fieldbus system. The closed-loop controller is connected to the fieldbus system in the control system software via the device description. Activation of the closed-loop controller itself is realised by communication protocols or the control system's function modules.

For software engineers and programmers, it is important to take into account the mechanical requirements, too, alongside the purely electrical machine programming. Only when the dynamic possibilities of the mechanical system are correctly combined with the those of the motors and servo drives can an application be operated efficiently.

To do this, the programmer needs among other things:

- Software for the parameterisation of servo drives
- Programming tools for the control program (motion control)
- Tools for integrating the servo controller into the control system
- Data on the dynamic response and the kinematic behaviour of the connected mechanical system
- Electric circuit diagrams (E-CAD) of the selected components

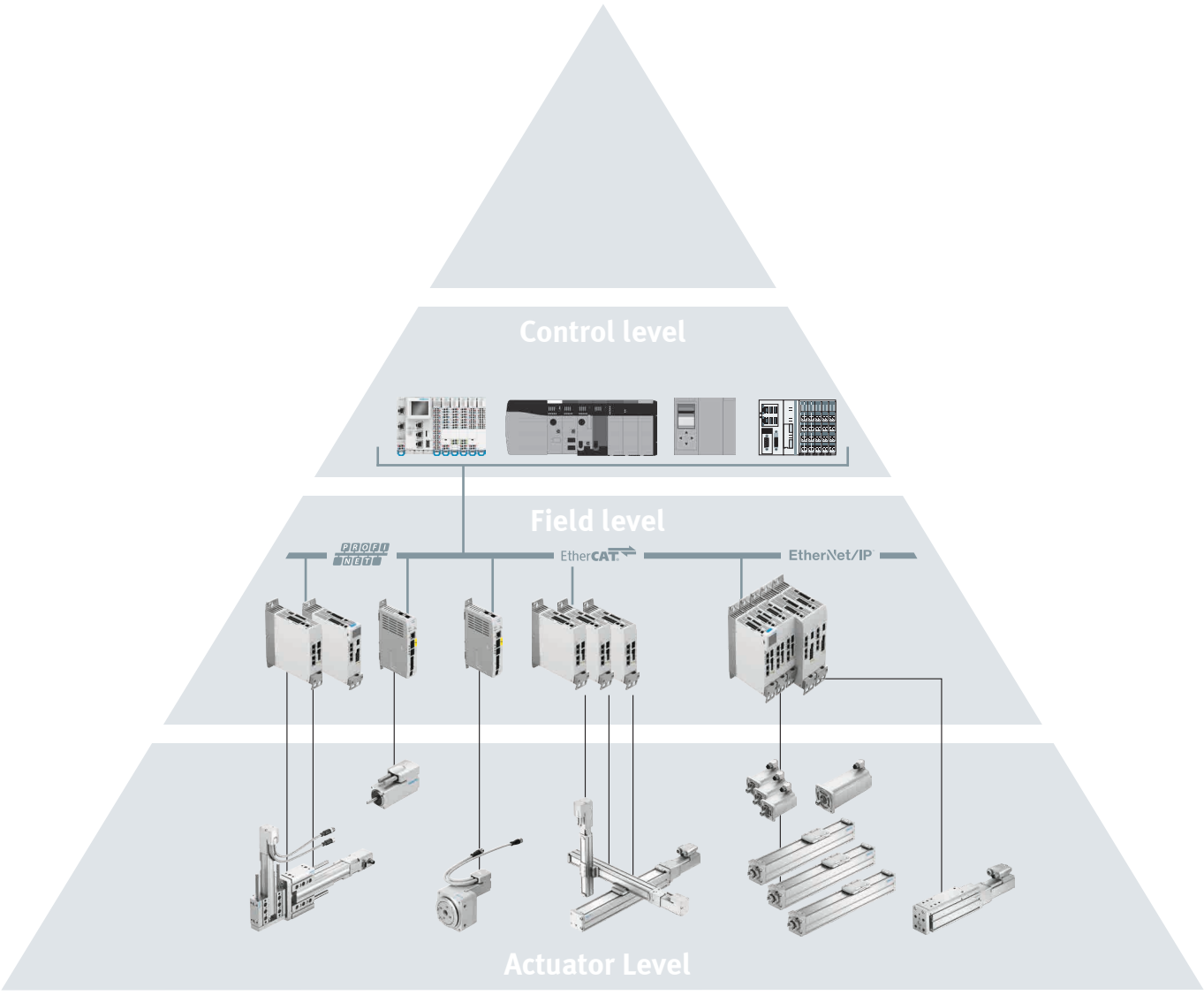
**Control level**

The control level comprises the control components of the machine or the system and/or of a module or a cell. There are two fundamental architecture characteristics: centralised or decentralised. The former means that all system participants are fully controlled by a controller whereas the latter is the cell or module controller of individual system parts as well as the high-performance preprocessing of individual automation modules.

The challenges here include, for example, finding the best architecture for a particular application. Demand of end customers for different controller manufacturers or regional differences in preferred manufacturers and fieldbus protocols are also making software engineers and programmers ask themselves how standardised machines can be designed and how much control-specific knowledge is required. It is important to note here that manufacturer-specific programs are needed for each control system. This applies to different programming languages as well as to fieldbus protocols or function modules.

To do this, the software engineer and programmer require, among other things, for each control manufacturer:

- Programming tools for the control program
- Fieldbus protocols and manufacturer-specific function modules
- Data integration into the production cell or (factory) level




Classic automation pyramid with its different hierarchy levels

## Status quo

**The electromechanical drive package**
Whether for mechanical or control systems, an almost overwhelming number of products, components and solutions is available from different manufacturers, all with their own interfaces, hardware solutions, programming languages, software systems, communication protocols, etc. This means that machine builders constantly have to spend time combining and integrating them into their machines. The task is therefore always the same: how can a mechanical axis, a servo motor and a servo drive be easily combined so that they complement each other perfectly? And how can this electromechanical drive package be integrated quickly and easily into the controller?

**Integrating drive systems into the controller**
Especially the integration of drive systems (servo drive and servo motor) in different controllers is a major challenge for machine builders. The software solutions and tools for design, parameterisation and programming from different manufacturers are usually very different, with data being inconsistent and not interchangeable.

As it currently stands, technology makes it possible to combine at least a few servo drives from different manufacturers into one automation system. This is helped by established standards such as EtherCAT, ProfiNet, Ethernet/IP.

Despite all this, establishing a connection/communication between the participants so that the data can be transferred without error is often a complex process. The time and effort required for testing and commissioning is often difficult to estimate in advance due to its complexity. This leads to a considerable risk in terms of effort, time and costs.

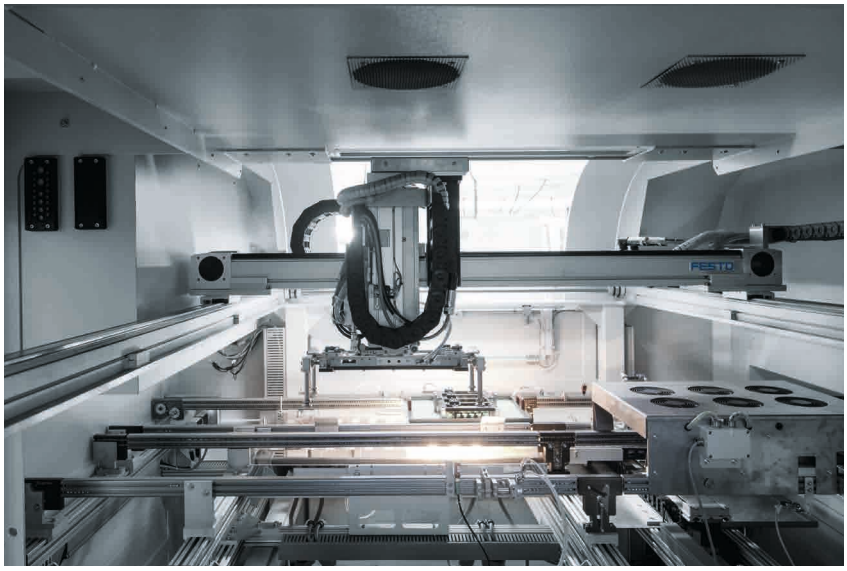
## Different challenges for manufacturers of special machines and standard machines

Compared to a special machine builder, the focus of a series machine builder is quite different. Large series machine builders standardise their drive solutions much more compared to special machine builders, who have to cater for the highly individual wishes and requirements of their customers.

**Why standardise?**
The more application-specific the design of the drive systems is, the more efficient the machine will be. Since perfectly coordinated and optimally connected components in series machines repeat themselves, the entire series benefits. That is why series builders invest much time and effort in design and integration and are therefore familiar with designing uniform electric drive systems, standardising them, incorporating them into control systems and commissioning everything later on. They need the hardware and software in their machines to fit together and the interfaces need to be optimally matched, regardless of the individual suppliers for the drive systems and those for the controller.

**Why customise?**
The challenge faced by special machine builders is flexibility, for their customers often define the control concept in advance. They need to reconfigure each machine individually time and time again, designing and commissioning it in line with their customers' architecture. This can lead to frequent changes in the automation hardware and control concept. In addition to just the hardware, interfaces need to be redefined and managed and software tools have to be used. This needs to be done as quickly, simply as well as reliably without too much time being spent on getting used to them.

> Series machine builders and special machine builders have quite different requirements when it comes to automation platforms and connectivity. Series machine builders standardise their drive solutions much more while special machine builders require highly flexible solutions to enable them to respond to the very individual wishes and requirements of their customers.




Individual electromechanical drive solution in electronics production

# Hardware and software solutions from Festo

## Making developments quicker, easier and more flexible and reducing the time to market

Festo already set about understanding all the different aspects related to the topic of connectivity many years ago, especially in relation to automating industrial motion, from the workpiece to the controller and up to the cloud, i.e. from mechanical components and servo drives right up to intelligent controllers and modern cloud services. This is complemented by modern cloud solutions for industrial automation, known as Industry 4.0.

In our own production – e.g. in the Scharnhausen Technology Plant – we have experienced ourselves where the difficulties and challenges lie. We have recognised how complex tasks and solutions can be and have learned how to deal with this complexity ever more efficiently. At the same time, we have always realised that our customers will benefit hugely from this experience, as we know what is required when it comes to connectivity in industrial automation. Right from the start, our goal was to work out and offer solutions to our customers that support them, so they can concentrate on the essentials.

Festo can now offer convenient solutions that above all provide one thing: they save time-consuming and cost-intensive work when configuring and commissioning machines.

> The constantly shortening product lifecycles of modern machines are increasingly forcing manufactures towards a mechatronic design with a high degree of modularity. This is true for both hardware and software. This is precisely where seamless connectivity comes in, as it effortlessly and reliably combines hardware and software components with solution packages to create an overall system.

State-of-the-art automation technology in the Scharnhausen Technology Plant

## Uniform, compatible hardware and software solutions from one manufacturer

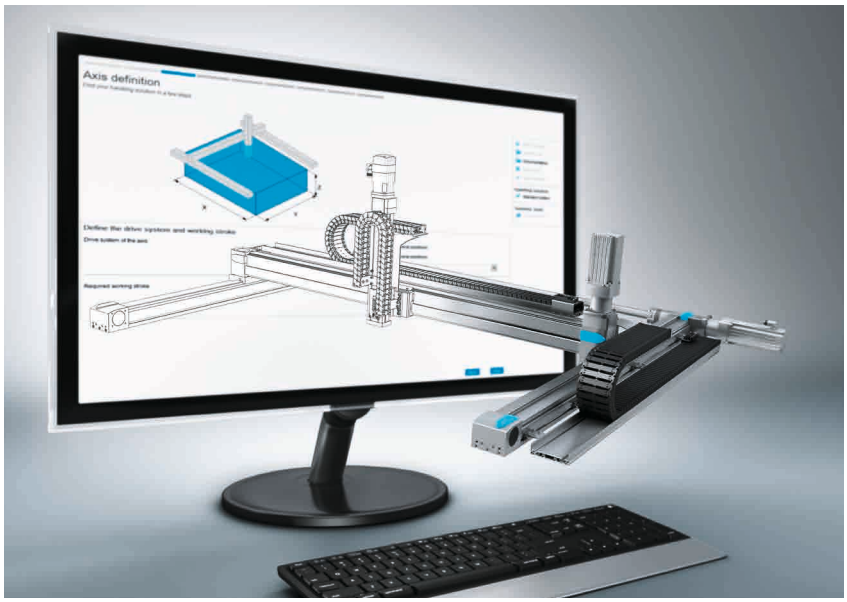
When developing our automation platform, great emphasis was placed right from the outset on seamless connectivity. The mechanical system, the drive system with motor and controllers as well as the software modules are designed as one unit – and this applies to the mechanical interfaces as well as to the electrical and intelligent interfaces. Compatibility with the many controller manufacturers was a major priority. That is the only way to uncover new potential and design production systems that are flexible, efficient and individual. Regardless of whether this is for a series machine or a special machine, a new design or a variant.

Our matching and scalable modular systems with automation components at all levels facilitate the design of versatile machines and control concepts that not only save costs and time but also offer flexibility and individuality.

- Mechanical versatility Each application requires different mechanical motion, either linear or rotary. The mechanical modular system from Festo offers all the common mechanical motion systems with interfaces that match one another as well as the workpiece and the motor.
  - Electric drive with piston rods
  - Mechanical systems without a piston rod with different drives (spindle and toothed belt)
  - Cantilever axes and slides
  - Grippers and rotary and swivel modules

- Optimal configuration of mechanical and drive systems
  The automation of motion is not overly complex in principle. But sizing the solution correctly, designing it efficiently and at low cost requires a lot of knowledge about the electromechanical context as well as the options for the control technology of the servo drives. The solution can only be optimally designed and safety factors kept to a minimum provided the software knows all parameters – those intrinsic to the application, the product and the system – and then links these with experts' know-how. Based on this development hierarchy, both in the mechanical system and the servo drive technology, Festo knows virtually all the required parameters and has developed software tools that meet this need.
  - PositioningDrives for individual axes
  - Handling Guide Online for complete 3D handling solutions

> Handling Guide Online: the right 3D handling system including a CAD-model in 3 steps and just 20 minutes – suitable for the kinematic and dynamic requirements of the application.




Configure standard handling systems quickly and simply with the Handling Guide Online

- Simple, fast commissioning of the electromechanical drive system When all connected components and their parameters are known, commissioning can be carried out quickly and easily – ideally using the same software each time for all automation components. In the commissioning software from Festo, the appropriate plug-ins for components are installed and then connected through dragging and dropping. This is the only way in which electromechanical drive solutions can be easily commissioned and incorporated into the entire system. Any product changes that are needed for the concept can be performed quickly and reliably without excessive effort.
  - Festo Automation Suite

- Improvement of machine reliability and utilisation Perfectly coordinated and optimally connected components – mechanically and electrically – will ensure the reliable operation of a machine. Machine reliability leads on the one hand to a higher level of machine utilisation, and on the other to a higher production and product quality. Additional tools and new concepts enhance machine reliability:
  - condition monitoring
  - Predictive maintenance

> Festo Automation Suite: thanks to the initial commissioning assistant, the electromechanical drive system can be commissioned in 5 steps and the servo drive can be integrated in the control program of the CPX-E in 2 clicks.

## Integration of servo drives

Integrating servo drives into a controller can be a demanding task.

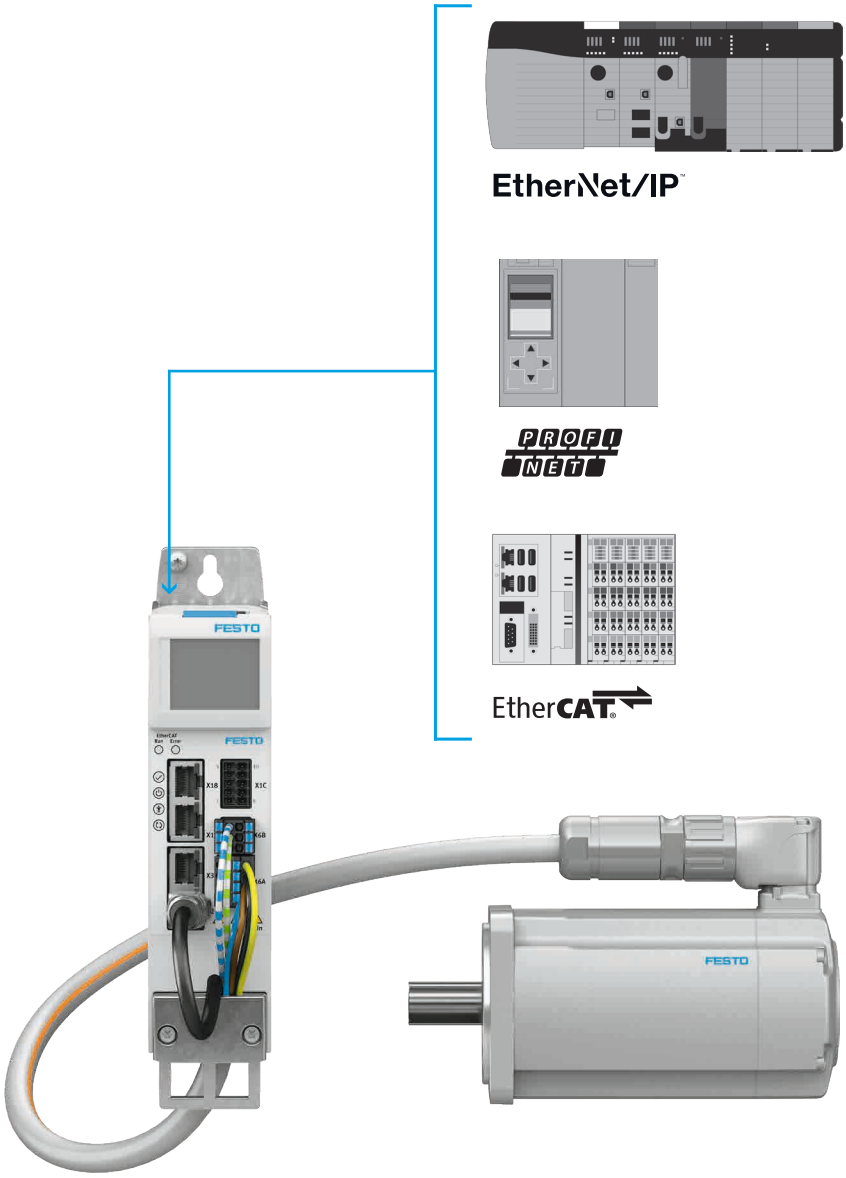
If both are from the same manufacturer, this is usually not too complicated. Suitable software tools and supporting documentation are generally available. Both participants known each another, data is exchanged automatically, both speak the same language and the function modules are clearly described.

If, however, a servo drive by manufacturer A is to be incorporated into a controller by manufacturer B, it is a different situation. This may be the case when standardised subsystems, electromechanical servo drive systems or machine modules have to be re-adjusted to the customer's requirements and controller manufacturers need to be switched. Or when the machine was sold to another region of the world and a different controller manufacturer is prescribed. In these cases integration can quickly become complex and laborious, costing time and money, and this usually means starting all over again with the programming.

Software engineers or programmers then face new challenges.
In addition to changes in software and hardware platforms, they are often also confronted with different fieldbus systems, software modules and data protocols. This means they have to master several languages, they need to understand how the individual components behave in relation to one another and how they are operated. Much time is spent before an electromechanical drive system of this type can operate without any problems, and even then the machine workflow will often have to be programmed too. The same applies for commissioning and, if time pressures from the fast-approaching delivery date are added to the mix, this can lead to unscheduled delays due to technical difficulties.

> Cross-manufacturer integration of servo drives and servo motors in control systems is quick and easy thanks to the connection to intelligent software support.

The latest generation of servo drives and servo motors from Festo, together with the intuitive commissioning software Festo Automation Suite, makes this integration easier and speeds it up significantly. This can be integrated virtually seamlessly into all commonly available, Ethernet-based external controllers and users will not even notice that the hardware manufacturers are different. The parameterisation and performance of a servo drive from Festo will be just like a closed-loop controller from the controller manufacturer. And the servo motor will automatically relay its data to the closed-loop controller and thus to the software via an electronic rating plate. All this creates reliability and avoids errors, considerably reduces system configuration and commissioning, particularly when combined with the appropriate electromechanical components.




Servo drives with controller CMMT-AS and motor EMMT-AS integrated directly in Ethernet-based control solutions

## Software for commissioning the complete electromechanical drive package

Commissioning the servo drive system as well as the relevant mechanical system is one of the final steps in the engineering process and at the same time probably the most important. It should be done quickly and easily but also reliably – without any crashes.

The engineering process starts with the configuration of a mechanical system, an individual axis or a 3D handling system; during this phase the engineer will usually also stipulate a suitable servo drive system. Configuration of the electromechanical drive system includes all the relevant data such as for example the types and sizes of axes, motors and closed-loop controllers, and, if required, the necessary gear units and much more besides. Engineering software is often used during this stage, as it replaces time-consuming manual calculations, which often present safety risks, with just a few clicks. The data, key values and parameters of the selected components that are determined at this stage will be required again subsequently for other software tools e.g. during programming and commissioning.

The application programmer will program the machine a few weeks or even months after the design phase. His or her tasks will be to program the user program and parameterise the drive controllers. By having the design data from the configuration readily available, programming and commissioning are significantly simplified and made much faster and more reliable. The controller parameters and the functions of the service drive can then be transferred automatically from the design data; there is an automatic check for updates and the latest firmware downloaded if required.

By consolidating individual, previously independent software tools on one platform, data and parameters are more consistent and user-friendly to use, so the process becomes faster, simpler and more reliable. The universal software platform for the entire engineering process fits in perfectly with the concept of seamless connectivity, from the mechanical system to the cloud. It can be used by different people at different times and is simplified by a uniform look and consistent operation.

Festo Automation Suite: commissioning of electromechanical drive systems in 5 steps

> The PC-based Festo Automation Suite combines parameterisation, programming and maintenance in one program and enables the entire drive package, from the mechanical system to the controller, to be commissioned.

**Publisher:**
Festo AG & Co. KG
Ruiter Strasse 82
D-73734 Esslingen
www.festo.com/ea