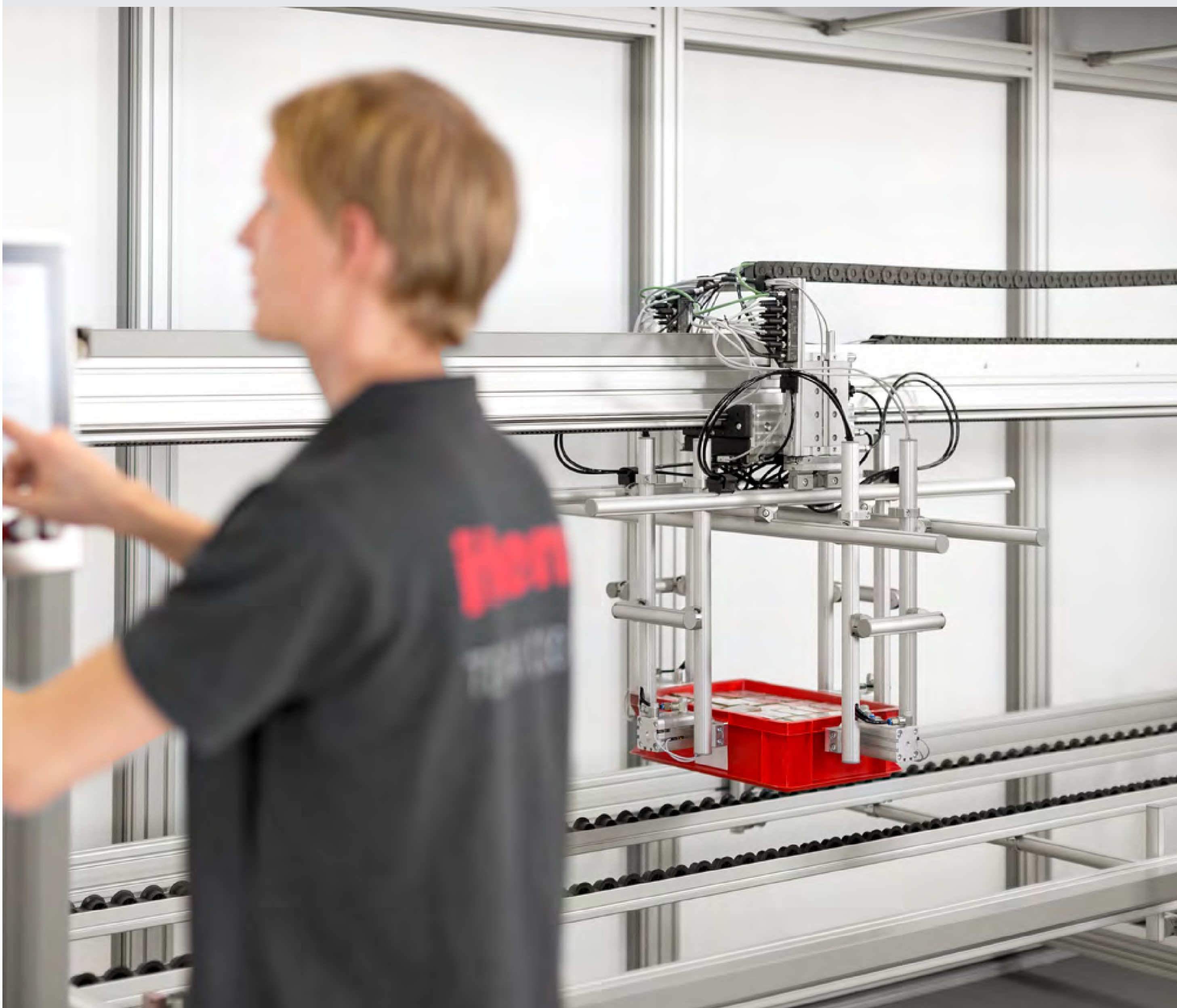
Automation in industry

The basics of linear technology



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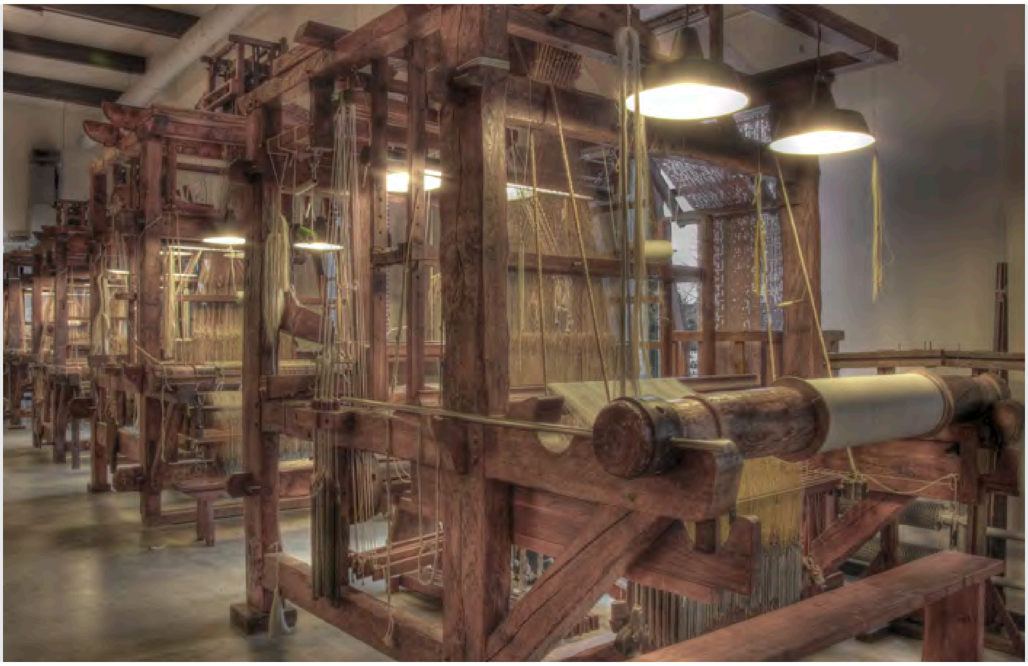
How this guide can help

Using machines to automate processes is an intrinsic part of modern production operations. Over recent years, a reduction in unit costs and increase in quality standards has led to huge efficiency gains in industry. However, to make the best possible use of these efficiency gains, companies must ensure that their machinery and plants are attuned to the specific requirements they need to meet.

This White Paper offers guidance on the use of linear technology in industry in order to help users preselect suitable technologies. It presents the fundamental technical approaches and offers a point of reference and a brief overview of the relevant advantages. As the range of products available has increased significantly with advances in technology, it is all the more important to focus on the core elements so as to speed up planning. This White Paper can also help users who don’t have a great deal of prior knowledge to assess the plausibility of an offer.

Overview: White Paper “Automation in industry”

Industrial automation is a very complex topic, which is why we have written two White Papers on the subject. This first part, “The basics of linear technology”, focuses on mechanical considerations and the decisions that need to be taken when selecting the most appropriate drive and guidance technology. The second part, “The basics of motors and controls”, focuses on the electronic components and the interplay between mechanics, controls and motors.



It was in the 16th century that the first mechanical looms were developed, driven by a water-powered system

A brief history of automation

Simple machines overcome human limitations

Man has always strived to overcome his physical limitations. The use of tools is one cultural technique that has been applied to complete tasks in a whole range of situations. In the beginning, these scenarios were mostly all about surviving, as indeed the Latin root to the word "culture" suggests ("cultura" translates as cultivation or agriculture). Homo habilis used the oldest known stone tools some 2.5 million years ago.

It was much later that modern man started to develop simple machines to overcome the limitations of his own precision and productivity. Archaeologists excavating graves in China have discovered jade rings that are over 2,500 years old, the rings being so uniform that it seems certain this hard mineral must have been machined. A repeated rotary motion has been used to gradually create a regular spiral pattern that can be found with minimal tolerances on all the rings.

The first industrial revolution witnessed an extraordinary surge in automation when the benefits of mechanisation were enhanced by steam power. From now on, the physical strength of people and animals was no longer a limiting factor and machines could produce goods that would have been unimaginable before.

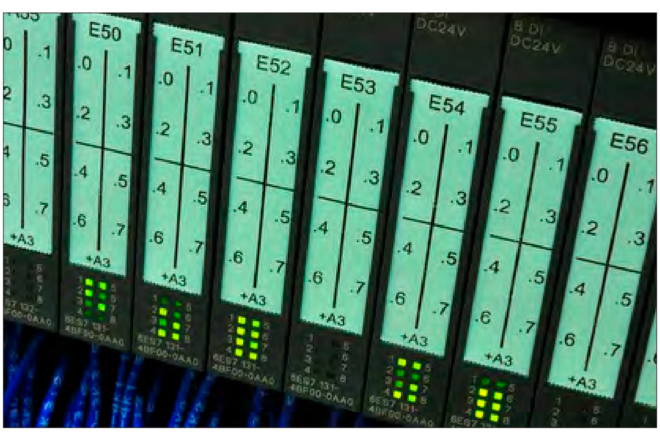
During the second industrial revolution, production times were cut dramatically with the introduction of the production line, which therefore significantly reduced costs for consumers.

Even today, the primary purpose of automation is to deliver results that can be repeated to a consistent quality standard. Automation makes it easier to comply with standards by largely eliminating the errors caused by human intervention. Machines don't get tired either, and usually work faster than any person can. When identical workpieces need to be produced to a consistent quality standard, automation is an indispensable requirement if a company is to stay competitive.

Over time, machines and plants have become increasingly complex in design

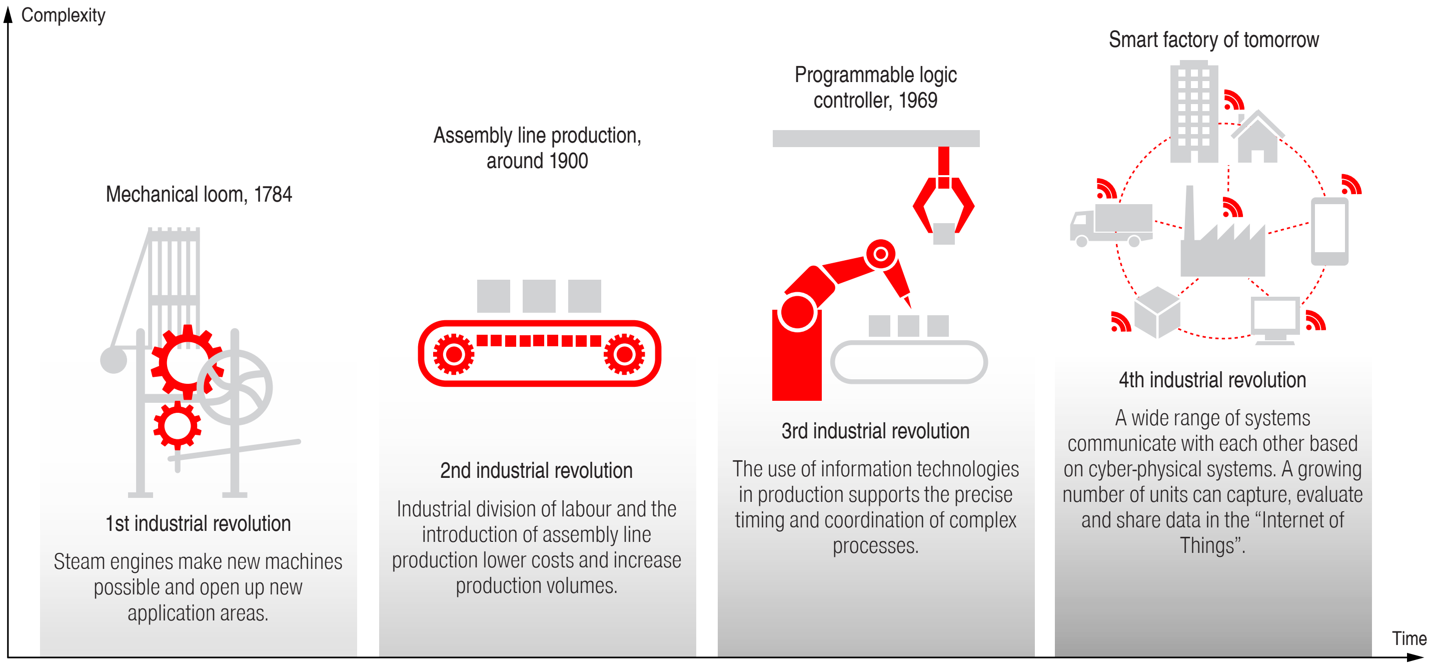
Machines become intelligent

Simple machines complete one process on endless repeat and even minor adjustments require large-scale conversion work in the production process. Developers therefore started looking for a process that would allow them to control machines on a situation-dependent basis. To do that, machines would firstly need sensors so that they could measure and assess conditions. Secondly, they would need an electronic brain so that they could process this information. The breakthrough came in 1969, when the first programmable logic controller (PLC) appeared on the market, heralding the third industrial revolution. The creators of this ingenious device were Richard Morley and Odo J. Struger. The Modicon 084 programmable machine control system was launched onto the market under the somewhat unwieldy name "Solid-State Sequential Logic Solver". The words "Logic Solver" point to the element that was particularly important to Morley. His control system was designed to draw logical conclusions from events and respond accordingly.



Programmable logic controller (PLC)

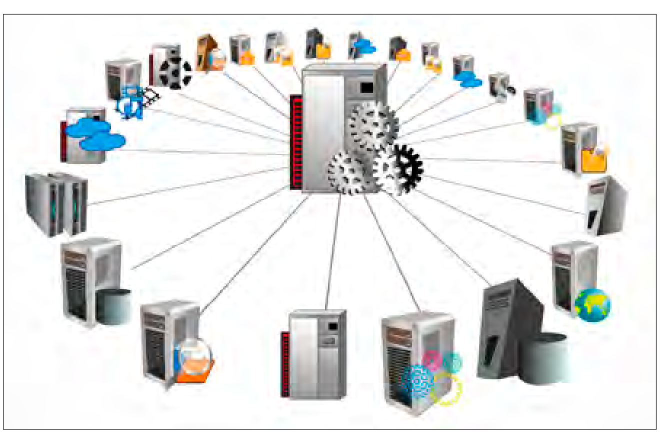
From as early as 1958, simple controls like the Simatic from Siemens had been able to count processes and stop after 100 cycles to change a magazine, for example. Genuine programmability that – like the Modicon 084 – would enable machines to react flexibly to events, came later. In 1974, Klaschka und Pilz launched the first PLC in Germany. Siemens followed suit almost immediately with the Simatic S3.



The industrial revolution timeline

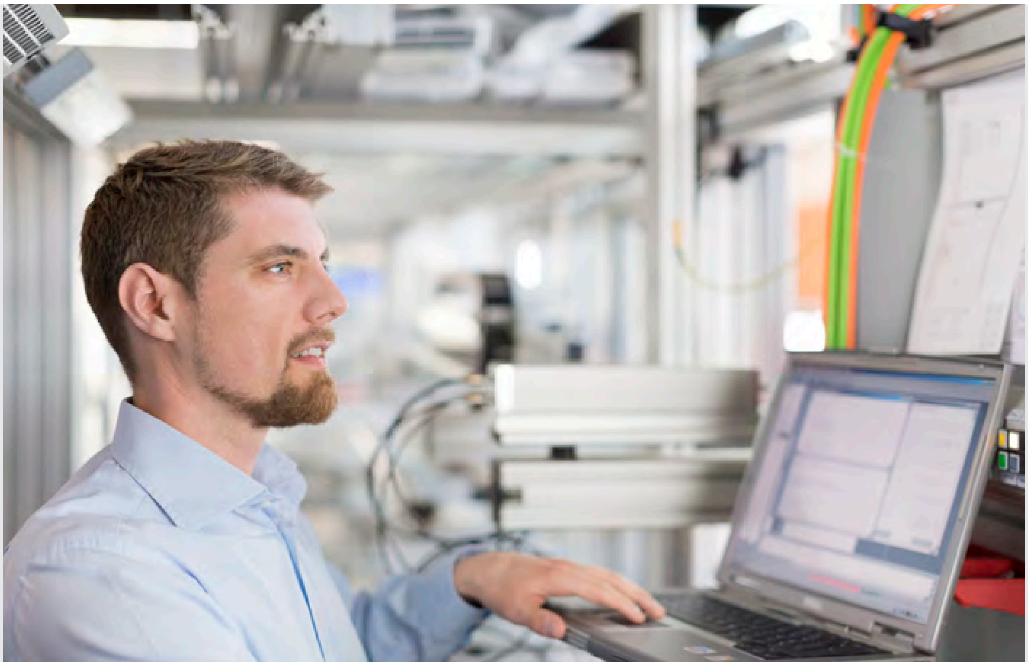
The closed systems of yesteryear have grown into multifunctional units. The choice of control system determines how many components a solution can control, how refined the processes are and how easily it can be coordinated with other systems.

Automation is increasingly changing from a process that focuses on the individual machine to a networked system. Machine-to-machine communication should make new types of value creation possible. In the upcoming fourth industrial revolution – dubbed Industry 4.0 – particular importance will be attached to the intelligent processing and transmission of data so that custom products can be produced with the cost benefits of machine-based series production.



A wide range of elements can be networked together via the Internet of Things

"Smart production enables us to master processes that are more complex than we could imagine today. The factory of the future offers a great deal more flexibility and robustness with the same high standard of productivity and quality – all while making optimum use of resources. This innovative approach to production brings a number of challenges such as how to increase automation while also customising processes, how to cope with large volumes of data and how to put in place sophisticated monitoring systems that can be used to manage entire value-creation networks," says Prof. Henning Kagermann from the German National Academy of Science and Engineering (acatech) in Munich.



Tomorrow's workers will be very independent, communicative and organised

Efficiency will be all-important in the future

As human labour in the production process has been increasingly replaced by machines, people have started to focus more and more on development and planning activities. Today, it is the task of people to ensure that companies continue to exist in the future and are not forced out of business by the growing pressures associated with competing on highly globalised markets. Prof. Kagermann believes that the future will bring even more major qualitative changes in industrial working practices: "Complexity, abstraction and problem-solving are three areas where all employees working in smart factories will face much tougher demands. What's more, staff will need to work on a very independent basis, have excellent communication skills and be able to organise themselves efficiently." Intelligent assistance systems will help employees to manage high-precision production reliably and efficiently.

One crucial issue – both at present and most certainly in the future, too – is efficiency. To achieve efficiency benefits, companies are increasingly focussing on their core skills, using resources economically and deploying advanced and innovative technologies.

Vertical integration, as has been pursued in industry in the past, is increasingly proving to be an inefficient approach. While heavy investment in machinery and plants ties up a great deal of capital, ever-shorter product lifecycles mean that companies have to be able to recoup costs increasingly fast. This has led companies to focus ever more closely on their core skills. That in turn has led to a drop in the vertical range of manufacture on the one hand and the emergence of in-depth and sometimes revolutionary specialist expertise in certain sectors of industry on the other. This advanced know-how and the associated innovative technologies can be bought in, thereby boosting the benefits of in-house production and/or the manufactured product. Securing more benefits for the customer means achieving a higher sales price. The end result is improved efficiency and a stronger position on the market.

Customer-focussed companies offer ready-made solutions for carrying out a very specific task. Standardised interfaces are also being defined to ensure compatibility between various modules. Pre-configured modules make projects much more straightforward, particularly in mechanical and custom engineering. Furthermore, throughput times can be reduced while simultaneously boosting the planning certainty for individual projects.

User-friendly start-up assistants make programming easier so that production can get under way faster

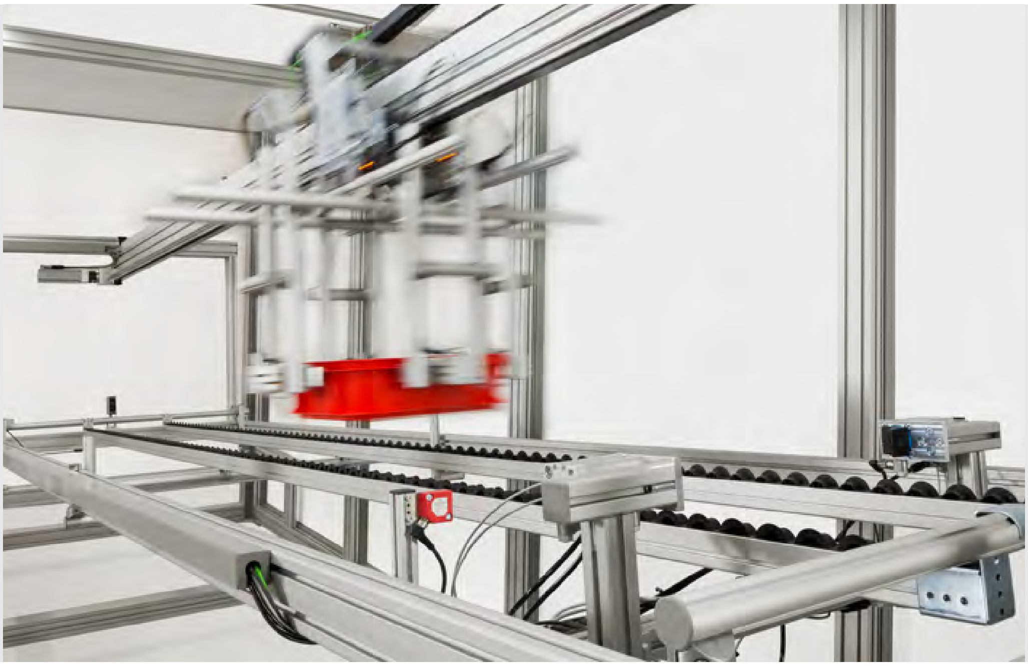
Technical principles of automation

Linear technology is a standard solution in industrial automation. It is robust, reliable and can be implemented at low cost. As the name suggests, these systems move along a straight line, or axis. A linear unit moves the slide (the carrier or carriage for the workpiece or application) forward in one direction and, in most cases, back again. Synchroniser shafts can be used to run two or more linear units in parallel and different linear units can also be combined to allow positioning in two or three dimensions.

Linear technology can be used to design complex movement sequences for a relatively low investment cost.

A powered linear unit is made up of the following components:

- A linear guide is a rail fitted with a slide that moves along it. The slide can only move along the rail in a precise linear motion.
- A drive element such as a combination of two reverse units and a timing belt can be used to move the slide mechanically.
- A motor performs the mechanical work by converting electrical energy into kinetic energy, for example.
- A controller is responsible for ensuring the motor doesn't just supply the kinetic energy but also executes the right number of revolutions in the right direction and at the right time as appropriate to the movement that is required.



Linear technology can be used to tailor complex movement sequences to specific production requirements

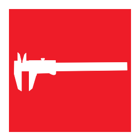
Selecting an appropriate linear unit depends firstly on the workpiece that is to be processed or machined and, secondly, on the specific production environment. The following section sets out key considerations when selecting an appropriate linear unit:

Payload

The payload is the weight that the slide should be able to transport. Heavy workpieces or tools need appropriately robust guides and drives. How much weight a slide can carry will depend, for example, on the load-carrying capacity of the rollers. If a heavy payload is to be moved over a long distance, the cross-section of the support profile must be appropriate for the load in order to prevent excessive profile deflection.

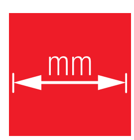
Speed

The faster the slide moves, the less time is lost between processing steps. Faster speed also drives up unit numbers and increases productivity in the production system.



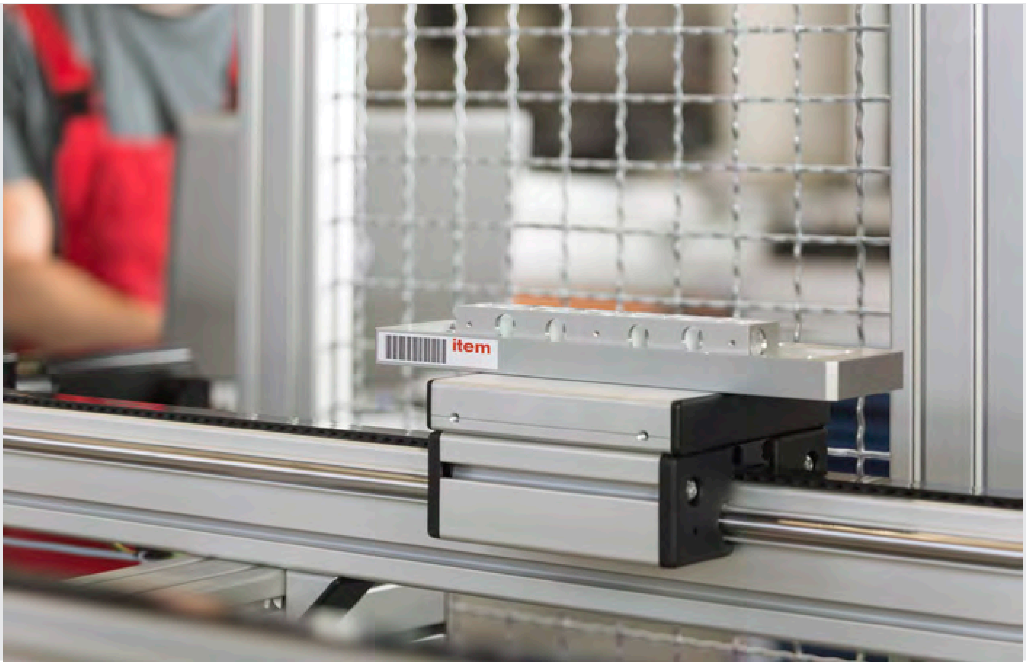
Repeat accuracy

This refers to the maximum deviation in a regular movement from point A to point B. In a system with excellent repeat accuracy, the slide will always stop precisely where it is supposed to, which improves the precision of machining operations. Low tolerances are the best way to ensure a pre-defined movement is executed reliably.



Maximum travel distance

Ultimately, the planned application itself determines the distance that a slide has to cover to complete the task. Certain drive and guide technologies will be more suitable than others depending on the travel distance in question.



A combination of timing belt drive and roller guide produces rapid, play-free movement

Linear guides

A linear guide is the core component in a linear unit. It determines the direction of movement, i.e. the linear path. It can be compared to a train travelling over rails. A linear guide is therefore made up of two elements – the actual guide (rail) and the corresponding transport element (slide).

A distinction is made between the following types of linear guide:

Roller guides

Roller guides use rollers that run on shafts. The shafts are usually cylindrical or semi-cylindrical rods fitted to a support profile. Rollers are bearings with a special profile designed to precisely encompass the shafts and support play-free motion while ensuring that the bearings do not jump off the shafts. The diameter and material of the shafts and rollers and the number and arrangement of the rollers can be altered to adapt the roller guide to a wide range of different tasks

T-slot sliders

T-slot sliders slide directly over a surface with minimal friction. In this type of guide, a profiled sliding shoe slides along a rail with a matching profile to ensure that the slide cannot move off track. T-slot sliders are ideal for applications that do not need to be completely free from play but do have to be as cost-efficient as possible to operate.

Recirculating ball bearing guides

Recirculating ball bearing guides are rolling-element bearing guides that – like roller guides – run along shafts or profiled rails. What makes them different is the arrangement of the rolling elements (ball bearings), which run along one line and are then returned along a second track. This functional principle of having multiple points of contact along a line helps to minimise friction and ensure that forces are distributed efficiently. Recirculating ball bearing guides can accommodate high loads in a small space.

Ball screw units boast high positioning accuracy

Drive technologies

Cutting-edge drive technologies have been optimised for different tasks. They can be very fast or exceptionally accurate. Ultimately, it is the choice of drive technology that largely determines the overall performance of a linear unit. It also impacts on the precision, speed, carrying capacity and costs of a solution.

A distinction is made between the following drive technologies:

Timing-belt drive

A timing-belt drive supports extremely dynamic movements and therefore short cycle times.

In a timing-belt drive, a toothed drive belt locks mechanically around a toothed pulley that is driven by a motor. This mechanical interlocking eliminates slip and ensures that high forces can be transmitted. The system can also reverse its direction rapidly and accelerate large masses.

A timing belt comprises steel cables in a polyurethane sheath, has a long service life and supports a smooth running action. Because the belt itself has a low mass, it takes little energy to move it on its own.

Linear units with a timing-belt drive can be built in virtually any length. As a result, they produce Linear Units that combine high drive forces with long travel distances. The drive effect is applied where the timing belt is reversed.

When using this type of drive in a vertical application, steps need to be taken to ensure the slide does not run out of control if there is a power cut or similar scenario. Unless a motor brake is fitted, the timing belt can be moved with ease and therefore does not automatically hold its position.

Ball screw unit

A ball screw unit is used when a great deal of power and precise positioning are required.

This is made possible by the drive principle: A ball screw unit is based on a precision spindle. The speed and positioning accuracy of the system are largely determined by the lead on the thread. A non-turning drive nut that houses ball bearings is fitted to the spindle. These ball bearings circulate in the thread and ensure that the nut moves along a straight axis as the spindle turns. Because the ball bearings are very slightly larger than the track in which they run, they produce a pretensioning effect that eliminates play and supports load-carrying capacity. Using a spindle with a large lead boosts the travel speed that the ball screw unit can develop.

The length of the spindle limits its revolution speed. Consequently, when aiming for high driving rates, a spindle with a large lead should be given preference.

This design is less prone to uncontrolled slide movement in vertical applications – due to the transmission ratio of the ball screw unit, the drive has to provide low braking torque.

> *The rack drive is a robust linear drive that can be used to move heavy loads.*

Chain drive

A chain drive is resistant to problems caused by soiling, can transfer high forces and is also ideal for vertical movements. The robust chain comes into use when absolute reliability is required, including under tough conditions.

Similar to a timing-belt drive, the rotary motion of the motor is transferred to a continuous chain. The drive cannot slip.

Linear Units with a chain drive transfer large forces in the direction of travel, but are limited in terms of positioning and travel speed due to their design. However, they exhibit excellent failure load, which means chain drives are often used to build lifting doors and other vertical applications.

Because the force in a chain drive can be converted into a rotary motion via sprocket wheels positioned anywhere on the Linear Unit, this design is particularly well suited to building conveyor systems with rollers. In fact, there are hardly any alternative solutions in this application scenario.

Compared to other Linear Units, those that use steel link chains require more maintenance work. It is also important to ensure the system is adequately lubricated and to check chain tension regularly.

Rack drive

A rack drive is used when heavy loads need to be lifted and a high level of repeat accuracy is required. The driven gearwheel interlocks with the straight rack to eliminate the possibility of slip. The rotary motion of the drive motor is thus converted directly into the rectilinear motion of the slide.

This enables two applications: Either the load travels with the driven gearwheel, or the drive is locked and the load travels with the moving rack.

The rack drive is a robust linear drive that can be used to move heavy loads. A high standard of positioning accuracy is obtained, even on long stretches, as the rack does not stretch out when under load.

Linear units with a rack drive also transmit power securely in vertical applications.

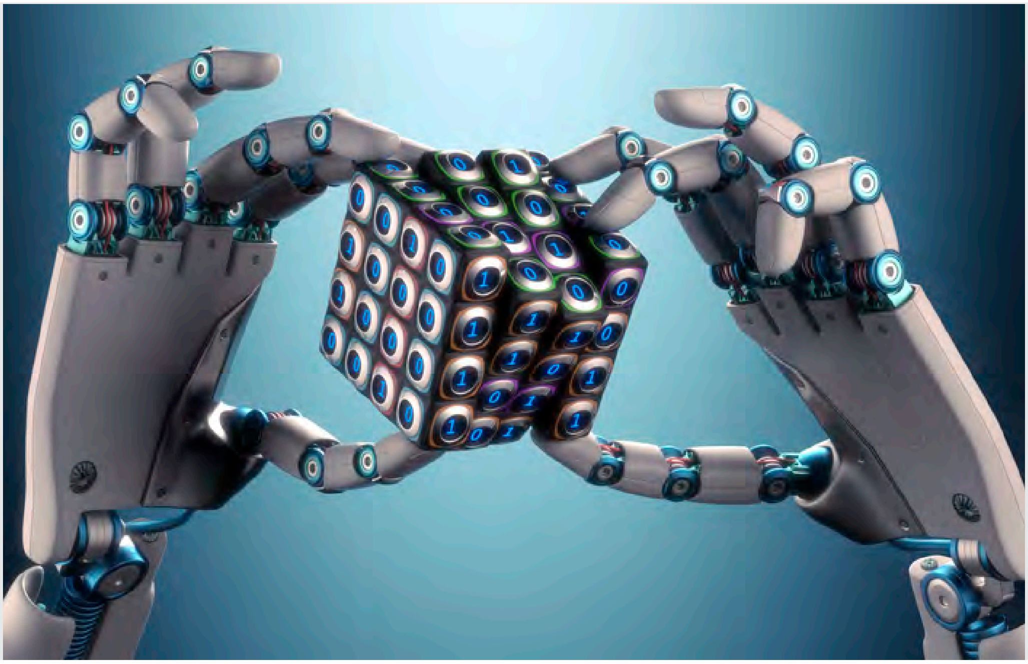
Cyber-physical systems network all the elements involved in the production process via a data infrastructure

Summary

Over the course of the third industrial revolution, the automation of processes has increasingly phased out human labour. Linear technology plays a major part in industrial automation tasks and can be used to build reliable, high-performance, multi-axis handling systems that execute movements in three dimensions. The ability to assemble linear systems such as these quickly and easily in industrial environments helps to increase capacities and thus boosts cost-efficiency.

Thanks to the diverse range of drive technologies and guides that is available, systems can be selected as appropriate to a company's specific production requirements. Before purchasing a system, it is important to determine the importance of factors such as payload, travel distance, repeat accuracy and speed for production. Drive technologies and guides should be selected in light of the relevant requirements.

The system as a whole – comprising linear guide, drive and slide – can be assembled and installed from specialised components that are appropriate to the task. As production processes are becoming increasingly streamlined, it is advisable to opt for ready-to-install linear units that can be installed directly, without the need for complex design or assembly work. This means that no specialist expertise is required for installing shafts or timing belts, for example. That in turn lowers costs and saves a great deal of time that would otherwise need to be spent on assembling individual components.



Big data: The cost-effective collection and evaluation of data is playing an increasingly important role

Outlook

Today, automation is on the cusp of another major change. The concept of Industry 4.0 stands for the large-scale integration of information and communication technologies – the networking of things, services and data in production.

The Internet has very quickly worked its way into virtually every aspect of our lives, creating new opportunities, particularly in production. The term “Big Data” stands for the networking of multiple software systems that share information and for the growing extent of data capture. Cyber-physical systems network all the elements involved in the production process via a data infrastructure. As a result, data and parameters from all the components involved in production – such as tools, factory equipment, products and machines – can be recorded, processed and evaluated in real time and parameters can be automatically reset.

Real-time data capture and online process control enable companies to respond to customer requirements more rapidly and manufacture a large number of product variants in small batch sizes cost-effectively. New, customer-specific products and business processes that are still unimaginable in today’s conventional production systems are becoming a reality.

The second part of our White Paper on automation in industry describes the electronic components in the overall system of a driven linear unit.

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