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### Sucess Stories Print & Paper Industries

The Print & Paper Special 2016, a special edition of our PC Control customer magazine, is a collection of selected application reports about print and paper machines which have been realized with Beckhoff technology. The wide range of applications with varying degrees of complexity will give you an idea of how versatile the solutions are that can be implemented with the open and universal PC- and Ethernet-based control technology from Beckhoff and the benefits it provides.
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Touching the future with Beckhoff
End-to-end digital workflow throughout the complete production process and the growing demand for individualized print and post-processing of print goods are the major driving forces for trends such as Print 4.0. But what is Print 4.0 in detail? Hardware or software? Mechanical solutions?

Industrial PCs with realtime multi-core and multitasking technologies, PLC and motion control combined with servo drives and eXtreme Fast Control I/O products in conjunction with software intelligence realized with the engineering system TwinCAT – these are the Beckhoff solutions for new automation technology used in a multitude of applications worldwide, and also in a broad variety of machines in all parts of the print industry.

So let us take a look at the future: Print 4.0 is discussing end-to-end digital workflow and individualized print processes. Beckhoff supports industry-specific future trends with the foundational technologies for Industrie 4.0 and IoT communication. These enable cloud-based business intelligence and end-to-end digital workflow processes that can be communicated via standardized industrial and IT-based protocols such as OPC UA, MQTT and/or AMQP. TwinCAT Analytics allows the next level of machine engineering and predictive maintenance applications that can be implemented with cloud or local server based big data collections and analysis functions, increasing plant performance by avoiding down-times.

So, how does individualization of products during print and finish processes work effectively in a mass production plant that has been tuned to high efficiency? One major point is obviously MES application software combined with end-to-end digital workflow processes down to the level of machine – machine and/or machine – sensor communication. The TwinCAT automation software suite includes all necessary libraries and communication technologies to combine the top business intelligence level down to the sensor.

Furthermore, concerning the “mechanical” handling of print goods (transport, stacking, bundling etc.), the Beckhoff eXtended Transportation System (XTS) enables software-guided flexibility in handling print goods allowing variations of sizes and/or formats, or different quantities in stacking and stitching processes.

Combining standard control algorithms with support for communication protocols into cloud and/or server-based systems based on Industrial PCs and modern software platforms such as TwinCAT offers an entry into Print 4.0 based production concepts and even enables new business models in the print industry. End-to-end digital workflow concepts including the mechanically flexible XTS enable seamless individual print and post-print handling in various formats and sizes – all part of the Print 4.0 concept.

Please enjoy some of the market players’ applications realized with Beckhoff illustrated in this PC Control Special!
Powerful control and drive systems in the A10 stacking system provide effortless machine operation by a single person.

Fast and highly accurate processing of signatures

Precision, speed and efficiency are critical in the printing industry and for related equipment suppliers in the marketplace. With its A10 stacker for processing folded signatures, machine manufacturer MBO was able to meet the highest stacking requirements with integrated, modular and highly scalable PC-based control technology from Beckhoff.
MBO Maschinenbau Oppenweiler Binder GmbH & Co. KG, based in Oppenweiler, Germany, has been active in the binding and print processing field for over 50 years. The company’s extensive expertise is readily apparent in its new A10 signature stacking system with a horizontal layout that makes it possible to process folded signatures quickly and effortlessly with only a single operator. According to MBO, “The signature bundler is designed for quick and easy training and operation, as well as for high processing speeds. Furthermore, the high quality of the resulting bundles of compressed signatures (folded printed sheets), including automatically inserted boards, offer further advantages in the following process steps of the workflow.”

One system for automation, control and measurement technology

According to MBO, the high performance of the new stacking system is enabled to a large extent by its control technology, which is entirely PC-based. “From the start, our choice of PC-based control technology for the automation of our machines was based on the comprehensive product portfolio from Beckhoff, which ranges from I/Os to drives and features a single software platform for engineering and runtime – TwinCAT. Moreover, the globally-available Beckhoff technical service is very important to us.”

The comprehensive Beckhoff system provides numerous benefits besides high performance, as MBO confirms: “The openness and modularity of PC-based control is a prerequisite for efficient machine development because it minimizes the effort to add new components and functionalities. The Beckhoff EL3356-0010 EtherCAT Terminal with eXtreme Fast Control technology (XFC) provides exceptionally high precision in the signature stacking process, because it seamlessly integrates advanced measurement with oversampling technology into the control system. Another example is the drive technology, where the AXS2xx 2-channel servo drives with an AXS801 TwinSAFE option card provide safe motion control in combination with AM8000 and AM8500 servomotors that offer increased rotor moment of inertia.

In addition to a host of EtherCAT Terminals, MBO selected machine-mountable EtherCAT Box modules that comply with the IP 67 protection standard. “We always try to collect as much I/O data locally as possible. This reduces the space requirements in the control cabinet and simplifies wiring processes. For the A10, we use the EP1018 and EP2028 8-channel digital I/O Box modules, as well as the EPS151 incremental encoder interface.”

Further information:
www.mbo-folder.com
www.beckhoff.com/print
Huafeng Printing Machine relies on PC- and EtherCAT-based control technology for advanced printing solutions

Huafeng Printing Machine Co. Ltd. is specialized in the production of printing and packaging machines. The company is located in Jiangyin City in China’s Jiangsu Province. Founded in 1998, Huafeng develops advanced rotogravure printing and dry-laminating machines. Huafeng has just recently applied a Beckhoff control solution in its 10-color direct-drive rotogravure machines used in packaging applications. Huafeng machines can print on all types of film, and consist of wind/unwind units, infeed units, inking units (up to 10), roll changers and a heating system.
“PC-based control technology gives us a competitive advantage,” explains Hairong Wu, Huafeng’s technology director, before listing the various advantages of PC-based automation: “HMI, motion control, media tension control, temperature control and color print mark registration are seamlessly integrated into the PC-based control platform, running on a single CPU with TwinCAT as the universal automation software. This allows us to print within tolerances as small as 0.1 mm and a speed of 330 meters per minute with 10 colors. This high level of performance is based on, among other things, the enormous processing power of the PC, fast EtherCAT communication and the high-performance AX5000 Servo Drive motion system.”

Highly accurate print mark registration with EtherCAT

To achieve an exceptional level of accuracy and speed in print mark registration, Huafeng has developed a print mark sensor with its own EtherCAT interface that communicates directly with the controller. The algorithm for the print mark registration is implemented in the TwinCAT PLC. “This increases the machine's speed and reduces waste significantly,” the technical director explains. “We are considering the implementation of eXtreme Fast Control (XFC) technology from Beckhoff in the future to better detect print marks and other signals.”

Further information:
www.hfels.com
www.beckhoff.com.cn
Traditional high volume printing methods such as gravure and web offset printing are battling against economic challenges; sheet-fed offset printing can look to the future only with cautious optimism today. Digital printing, on the other hand, promises better prospects, with the largest potential for inkjet printing. This is confirmed by Florian Fässler, Product Manager of Digital Printing at the Digital Competence Center (DCC) of Wifag-Polytype Technologies AG in Fribourg, Switzerland. He says: “As one of the three most renowned manufacturers worldwide, the former Wifag machine factory developed and manufactured newspaper printing machines. Since very few companies buy newspaper printing machines these days, the company decided not to develop any further new models in this area. In fact, digital inkjet printing is set to become the future for all departments of Wifag-Polytype Holding.”

In Florian Fässler’s estimation, the major challenges associated with digital printing are flexibility, on the one hand, and the productivity of printing, on the other. Only in finding balance here can printers profitably address the current trend towards individualization and personalization of materials. Digital inkjet printing is a matrix print method that generates a printed image consisting of a dot matrix. These matrix printers are familiar from office and home environments, where they are widely used as photo printers. However, these devices are characterized by slow printing speed, which is not acceptable for industrial printing.

Ultra-fast technology for sensitive print heads

The heart of an inkjet printer is the print head, through which a print image is generated by the targeted shooting or deflection of small ink droplets. “The print head is a commercially available system that is connected to our own printing units and the special Calmar electronics,” Florian Fässler explains. The print heads have quite a primitive interface. For example, there are no print heads with a USB interface. The Calmar project group’s particular achievement is the realization of control electronics that are industrially compatible and usable for all printing machines.

“The systems available on the market consisted of very complex electronic systems,” says Florian Fässler. “These were difficult to adapt, and scaling was not a simple process. Above all, they were not necessarily suitable for industrial
integration." However, the Calmar project team had planned to develop a robust electronic control system that could be integrated with a fieldbus. This was coupled with the goal of developing a platform of products that could enable simple and flexible usage.

In the evaluation phase, the project team decided to integrate EtherCAT and eXtreme Fast Control (XFC) from Beckhoff. Florian Fässler explains: "The reason we chose Beckhoff and EtherCAT is the openness of the technology. When we started our development activities three years ago, there was no comparable deterministically designed, fast and open system. This technology concept could be implemented into an FPGA, and the EtherCAT communication was simple to integrate and execute."

From interface to automation module

An important reason for the integration of EtherCAT and XFC into the Calmar electronics is the extremely fast operation of the bus and control system. EtherCAT is a deterministically operating bus with short cycle times and high data rates. The XFC technology from Beckhoff supplements this functionality with Distributed Clocks for a synchronized system time and a maximum deviation of less than 100 ns, as well as with highly precise Time Stamp functions for process data. Florian Fässler says, "For the synchronization of print heads, all associated controllers must be started at the same time. That means that all the tasks in every controller have the same time base and start simultaneously with the control sequence. The Distributed Clocks system ensures that all devices receive the Time Stamp within one cycle. The cycle time of 2 ms is evaluated by the system simultaneously."

For the integration of the Calmar electronic system, the project team created its own EtherCAT interface based on the EtherCAT IP Core ET1810 or ET1811. This enables both EtherCAT communication and application-specific functions to be implemented on an FPGA – all in a simple and convenient way, according to Florian Fässler: "The acquired tool made implementing the EtherCAT interface easy; it is very well documented." The result is a notable success, and Wifag-Polytype now has a flexible and robustly usable automation module in the Calmar electronics. Florian Fässler continues: "We can now conveniently engineer the print system with a configurator, regardless of whether it has two, 40, or even more Calmar cards. It is now much simpler to design and automate inkjet printing machines. In addition, there are more extensive diagnostic options available to us. Ultimately, we have an automation module that is ideal for industrial applications."

Secure on the inside, yet open to external connections

The Calmar control solution serves as an automation module for the digital printing machines from Wifag-Polytype Technologies AG, and is also marketed as an individual device within the framework of an OEM business model. The company’s own expertise is also available to OEM customers as a service. Florian Fässler explains: "The PLC architecture and the source code are open for OEM customers; the Calmar-specific libraries as well as the control room application can be adapted and extended on request. Connections to the outside world are also open, whether to ERP, MES, or other databases."

Wifag-Polytype Technologies AG acts with similar consistency within the Calmar project group: the team, which consists of both hardware and software specialists, works with .NET technology. The visualization is based on Microsoft Visual Studio®, into which TwinCAT 3 is integrated. "Visual Studio® is considered by some as perhaps something new or a special application for standard automation, but for us it’s a part of daily business. Our machines communicate over TwinCAT with the control room application, which was developed in .NET/Visual Studio®. The control room application takes care of the visualization," comments Florian Fässler.

Further information:

www.wifag-polytype.com
www.beckhoff.ch
One of i-Web’s key commercial printing customers is Japs-Olson Company in St. Louis Park, Minnesota. Japs-Olson produces printed products in a wide range of styles and formats, such as direct mail with high-quality UV coatings, single-sheet mailers (letter and envelope in one), direct mail with die-cut return cards, integrated labels, and many more. While attractive design, high quality processing as well as personalization combine to increase the response rates of end consumers, Japs-Olson also strives to reduce the cost of printing and mailing for its clients that advertise through direct mail. This requires machines with the highest level of automation.

Modular machine design boosts production flexibility

The machine modules i-Web developed for Japs-Olson are used in the finishing of printed items, i.e. for folding, cutting, perforating, gluing and stacking. “The flexible machine design and the use of state-of-the-art servo drive technology have solidified the relationship between i-Web and Japs-Olson, which has existed since the early 1980s,” explains Michael Murphy, the company’s president. “i-Web’s machine modules can be combined flexibly, which enables us to respond quickly to changing production requirements.”

Although i-Web has employed modern servo drive technology throughout its 30-year history, the company encountered limits in 2008, as president Bob Williams explains: “With our previous system we were only able to control a limited number of axes. We also had to use two different fieldbus systems for our I/O and motion control equipment. When we initiated the development of a new motion control platform, we focused on our network technology and a single bus system for motion, I/O and safety.”

After careful market analysis, i-Web selected the PC- and EtherCAT-based control platform from Beckhoff. “We were particularly impressed by the high performance of EtherCAT,” remembers Bob Williams. “Since EtherCAT enables communication with up to 100 servo axes in 100 milliseconds, we were able to easily resolve the previous bus system’s problems with regard to data throughput and communication,” reports Gilbert Peterson, Application Engineer at Beckhoff USA.

Hot-connect functionality, powered by EtherCAT

In finishing systems, multiple hot-connect groups must work together flexibly, because the individual machine modules have to be grouped together depending on the respective print job. Being able to quickly adapt to new product types with minimal machine downtime is therefore an essential requirement. “With EtherCAT and the AX5000 Servo Drives we are able to easily implement hot-connect functionality and control the many moving axes individually,” explains Bob Williams. “Since the central Industrial PC running TwinCAT automation software handles the entire motion control system, we no longer have to download
records when a single drive must be replaced. This is a huge benefit when the machine starts up. Even non-automation specialists can now exchange a drive as long as they have standard electrician and maintenance skills.”

**Integrated platform for PLC, Motion Control and safety**

As the automation platform for PLC and Motion Control, i-Web uses Industrial PCs from the C6920 and C6930 series with TwinCAT NC PTP for all its lines. The software handles all automation, including Motion Control and hot-connect functionalities. The visualization is handled with various Panel PCs such as the CP72xx series for arm-mounted installation or the CP67xx for installation in control cabinets.

During the printing process, the paper is transported through the i-Web machine via multiple direct-driven rollers. This requires precise synchronization with the additional finishing equipment. The stepper motors, which move the turning station, compensators, print heads, etc., are controlled via the compact EL7031 and EL7041 stepper motor I/O terminals.

EtherCAT also plays a critical role in the system’s safety. i-Web implements various emergency-OFF, interlock and other safety-related systems in its lines with the help of TwinSAFE components and the Safety over EtherCAT protocol. “The TwinSAFE I/O terminals enable us to implement significantly more safety technology,” explains Bob Williams. “Here, too, EtherCAT offers so much flexibility that we don’t have to implement a separate safety network.”

Since the finishing modules are flexibly added or removed to/from the line, each must have its own safety system. If, for example, an employee accidentally triggered an “open guard” condition, TwinSAFE makes sure that the system stops safely and in a controlled manner. This safe mode can be triggered for a single module, a zone or even the entire line if necessary.

**Remote access saves time and resources**

i-Web also leverages the benefits of remote maintenance and troubleshooting. “The PC- and EtherCAT-based control platform makes it very easy for us to access the system remotely. Since we have converted the entire machine communication to EtherCAT, we can monitor each system component remotely. EtherCAT includes extensive diagnostic functions such as failure detection with no bandwidth limitations. This has cut the time spent on troubleshooting at least 50 percent,” reports Bob Williams.

**Lean control design also reduces machine footprint**

The centralized control system with its distributed I/O components also enabled i-Web to reduce the footprint of its machines. “The compact design of the equipment reduces space requirements in the control cabinets by 50 percent. This also leads to cost and space savings throughout the entire plant,” adds Williams.

The company was also able to reduce its installation and testing costs, says Williams: “The time required to install the control components has been reduced by 75 percent, because we only need to connect a power line, an air line and a standard Ethernet cable to the machine modules during final assembly. This enables us to spend more time on customer-specific applications, which in turn solidifies i-Web’s reputation as true experts in the industry.”

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**Further information:**

www.iwebus.com  
www.japsolson.com  
www.beckhoffautomation.com

“Japs-Olson will continue to employ modern i-Web finishing systems, because they are highly automated and easy to configure on the plant floor,” says company president Michael Murphy.
XTS: Innovation potential – from motion tasks to intelligent Industry 4.0 elements
The eXtended Transport System (XTS) from Beckhoff opens up new solutions to realize compact, highly dynamic machine concepts. Even motion tasks that are nearly impossible to solve with mechanical engineering, or only achieved with considerable effort, can be conveniently and flexibly realized via software. Innovation potential thrives wherever creativity and machine design come together – be it in the simple linear motion of a “carriage mover”, or as an intelligent transport system within an Industry 4.0 application. The great variety of application possibilities are described below and illustrated based on current Beckhoff tradeshow exhibits.

The innovation potential of XTS is by no means limited to solving highly complex motion challenges. The system offers finely scalable customization options in terms of application requirements, e.g. relating to geometry, number of movers and functionality. It starts with simple applications, such as the purely linear movement of a carriage mover or the extension with a second mover to an XY table. The closing of the modular geometry, consisting of motor modules and guide rails, results in a continuous linear system with a number of movers that can be adapted to individual requirements. The full range of functions can be increased further by combining several XTS systems, using comprehensive TwinCAT function blocks and integrated robotics. If all these features are consistently leveraged in conjunction with condition monitoring and object-oriented programming, the result is a highly intelligent machine or production module, as envisioned by Industry 4.0 initiatives (Figure 1).

Figure 1: The Industry 4.0 XTS demo illustrates an innovative manufacturing process. The captured condition monitoring and energy data are stored in the Cloud, together with data acquired by a second pilot system.
Simple carriage mover and XY table functionality

Even for simple linear movements, XTS offers numerous advantages, thanks to its dynamic movement possibilities in combination with the replacement of mechanical functions through software. It deals with the tasks of a conventional linear motor with a movable carriage, although it is much easier to adapt to the respective application: with one or more motor modules, a suitable length can be selected with little effort. Furthermore, several of the wireless movers can be used if necessary, which greatly improves the flexibility in the application.

One example of how the ability to implement highly dynamic movements can be further increased with minimal mechanical effort is the functionality of an XY table (Figure 2). To this end, the carriage mover is simply equipped with a conventional linear bearing and supplemented by a second mover with a linear guide that is turned by 45°. The required motion in X direction can now be realized with jointly and similarly moving movers. The motion of the movers, relative to each other, creates the required Y motion via the two linear guides. In this way it is possible to realize any movement, including circular movements, e.g. for applying adhesives.

Here the system-related benefits of XTS come to fruition: the transport system is ready for use immediately after installation. Since power electronics and displacement measurement are included in the XTS motor modules, and the movers are completely passive, the measuring system does not have to be calibrated and the drag chains needed for conventional XY tables are no longer required. The result is an extremely compact, durable, and highly dynamic XY system. XYZ movements can be realized in a similar way with additional movers and corresponding kinematics.

Continuous linear drive with modular geometry

Due to the modular structure of XTS, it is not only possible to easily adapt the length to the respective application, but also to build a closed, continuous linear system using 180° curve modules. In addition, various curved motor modules are available, 22.5° inside or outside curve, plus 45° outside curve, which can be used to construct virtually any path shape. Examples include an S-shaped track (Figure 3) and a full circle (Figure 4).

Even during cornering, the movers remain under full control of the control computer, making controlled movements, i.e. defined process sequences, possible even at the deflection points. In this way, the transport system can be optimally adapted to the machine design. The XY table principle explained above works in this type of continuous section. The application benefits from mobile positioning tables, which can move continuously from one machining station to the other, in order to enable processes that apply adhesives or press on packaging lids, for example.

Rotary transfer machines are one of the many application possibilities of a circular XTS system. Currently available motor modules can be used to implement a full circle with a diameter of approx. 1.60 m (22.5° modules) or 70 cm (45° modules). Alternative guide rails are available for applications involving heavier weights, as shown in Figure 4. Furthermore, the motor modules can deliver their impressive dynamics with high forces up to 100 N. The range of XTS applications can be further extended with special guide rails from third-party suppliers, e.g. for high temperatures, aggressive agents, or heavy contaminants.

Despite all these features, XTS is by no means too costly or complex, even for essentially simple rotary table applications. If one of the processing steps takes significantly longer than the others, one could simply provide multiple instances of the respective station and integrate them into the process via software, thereby significantly increasing machine throughput with little effort. Other tangible
benefits arise from the high dynamics of XTS. Historically, conventional rotary tables are too expensive when the diameter exceeds 70 cm in applications with a desired cycle time of one second. Further benefits of XTS result from the lower weights that have to be moved, which reduces the number of required mechanical components as well as energy use.

**Complex geometries and movements**

Other ways to increase functionality, in the quest to solve challenging machine tasks, include combining several transport systems, whereby the installation position of each XTS can be freely selected. Figure 5 shows a product demo with a continuous XTS system and two linear XTS systems positioned at right angles to it. Each individual mover is represented as a servo axis, and a single Beckhoff Industrial PC with TwinCAT controls them all. Such a system is very efficient for sorting products, for example, and product changeovers are very flexible and quick to implement.

The motion functions that can be realized with XTS can go far beyond simple "Move from A to B" instructions, and not just in conjunction with complex geometries of the type described above. Additional features include automatic reversal of several movers for collision and jerk avoidance, mutual synchronization for holding or shaking processes in packaging applications, or for the XY function referred to above. This and other application-specific movement functions can be easily implemented with TwinCAT, using ready-made motion modules, resulting in a high degree of engineering efficiency. Virtually every mover is instantiated as an object-oriented program part, which reduces basic functions such as "dynamic backup with distance control" to simple parameterization, providing faster machine cycles through efficient program sequences.

**Seamless integration of robotics**

For applications requiring even more complex machining operations, XTS can be seamlessly integrated with robotics (Figure 6). TwinCAT Kinematic Transformation offers four different levels for this purpose, up to Level 4 with serial 6-axis kinematics, hexapod, and 5D kinematics. Using the mxAutomation library, commands can be sent directly from the PLC to a KUKA robot equipped with the KR C4 control system. Stäubli robots are also easy to integrate in TwinCAT.

The system benefits from the highly and appropriately scalable computing power of Beckhoff Industrial PCs, which can process XTS movements as well as robot kinematics on one CPU. This simplifies program handling and synchronization of subprocesses. Plus, the usual interfaces between the standard controller and the robot control are no longer required, which simplifies the exchange of variables.

**Individualized product transport with XTS as an intelligent Industry 4.0 module**

Offering high innovation potential, XTS seeks to make production processes more efficient and, above all, flexible. For this reason alone, it is ideal as a modern machine element from an Industry 4.0 perspective (Figure 7). A closer look makes this even clearer: in a traditional packaging or assembly process, the product is moved by a transport system and has to be repeatedly recognized, gripped, and possibly analyzed. In sensitive areas, such as medical and food technology, this results in a large number of mechanical components and sensors. In contrast, XTS enables the product to only be picked up once and then transported through the entire process with the same mover. Accordingly, the control program always "knows" where the product is and in what state.

This is supported by the object-oriented programming approach of TwinCAT, whereby each mover is mapped as a software module. Based on this direct
mapping of mover images and products, the "intelligent and self-organizing product", defined by Industry 4.0 as a vision of the future, can essentially already be implemented today. With each mover implemented as a software instance, it is quite easy to "carry through" or track and document not only the current process steps, but also quality data and error messages, for example. This information can be used directly in the production process. If, for example, an error occurs in the sterilization of food packaging, the affected pack, which is uniquely defined via the mover, can be taken through the entire process without printing or filling. At the end, the empty pack is simply discarded as a reject, without wasting additional material or filling content. The process cycle is controlled independently by each mover program, e.g. by automatically activating the next processing station, as soon as the previous mover has left this location.

A wide range of additional system data are already integrated into XTS, which can be used for efficient process management. For example, the speed-control demo shown in Figure 3 continuously monitors the distance between the sensor flag of movers and the motor module. Based on this value, the software detects whether the weight of the mover has changed, i.e. whether the ball has fallen out of the bowl due to excessive speed. This information can be utilized in many ways: is the product to be processed still in the workpiece carrier? Is the weight correct after processing? Was too much or too little adhesive applied? Typical condition monitoring also benefits from the information, for example, by making it possible to detect contamination on the guide rail or damage to bearings or rollers.

Figure 6: Through direct integration of robotics into standard PC-based control technology, TwinCAT software leads to simplified engineering and minimized processing cycles.

Figure 7: Using XTS, the product to be processed is usually transported through the entire process with the same mover and can always be clearly identified via the software model of the mover in TwinCAT.

Flexible on-the-fly batch processing in sorting machines

Further information:
www.beckhoff.com/XTS

Author: Uwe Prüßmeier, Product Manager Fieldbus Systems, Drive Technology, XTS, Beckhoff
PC-based control and TwinCAT automation software together provide the technological foundation for the advanced Industrie 4.0 and Internet of Things architectures that enable highly intelligent machines. TwinCAT Analytics, as a basis for comprehensive analysis functions, provides an important component of such architectures. It supports, for example, the ability to investigate the potential for machine optimizations, to facilitate both predictive maintenance and subsequent behavioral analyses and to manage a long-term data archive. TwinCAT Analytics also helps innovative machine builders create entirely new business models.
Even an intelligent machine may sometimes experience malfunctions. At such times, true intelligence can be recognized in the methods provided by the machine for analyzing the problem. Naturally, malfunctions will always be costly and time-consuming. However, they are all the more annoying if vital machine data and production parameters are no longer available that could otherwise be used to analyze and avoid these problems in the future. The end result is often that problematic behavior cannot be analyzed, and additional data logging mechanisms must be implemented. Even then, analysis cannot proceed until the problem occurs again. Specifically positioned to solve this lack of information, TwinCAT Analytics collects all process-related data for every machine cycle. This produces a complete log of all machine procedures. Depending on your requirements, the data can be collected and analyzed locally on the machine’s computer or within a cloud-based solution in your own network or over the Internet. Cloud-based solutions are particularly suitable for developing new business models, because they not only enable users to analyze behaviors after the event, but they can also analyze the data itself in order to take preventive action on the appropriate machine. Here, the key idea is “predictive maintenance”, something that machine manufacturers can offer as a revenue-generating service to their end customers.

No data? No analysis.
The basis of effective analysis is seamless data acquisition; users can enable this functionality by running the TwinCAT Analytics Logger on the control computer. It can also be easily configured in the engineering environment of TwinCAT 3: in the configuration interface, users simply activate the checkboxes for the data to be cyclically collected from the process image or application. The user can also specify whether the data should be stored locally or transmitted using a communication protocol. For either case, one can set up a ring buffer, useful to help ensure that local storage does not exceed the maximum possible storage capacity. If the data is communicated directly, a ring buffer can also bridge a temporary loss of connection.

IoT communication and cloud technology promote highly flexible analysis architectures
Direct transfer of data with the TwinCAT Analytics Logger is particularly suitable for developing new business models. It relies on so-called “IoT communication protocols”, which offer outstanding features for using cloud services. IoT protocols always set up an outgoing connection to a message broker. This decouples the communication so that the network nodes — unlike those using conventional client/server communication protocols — do not need to know one another. The communication participants all operate as the client. In this case, the TwinCAT Analytics Logger that runs on a control computer is an IoT client, “publishing” data to a message broker and storing it in what is called a “topic”. Note that topics can be hierarchical.
For example: myCloud/CustomerA/WoodWorkingMachine9/PackagingModuleB/Data

The message broker maintains a list of “interested parties” for corresponding topics, and other IoT clients can subscribe to these topics and their data. For example, an analysis server may be interested in the logger’s data or even a mobile application on a smartphone. Both of them are IoT clients, both subscribe to an appropriate topic and each receives a copy of the data. The beauty of IoT protocols is in their outgoing connections, because firewalls usually only block incoming connections. An elaborate opening of ports is no longer necessary. A further advantage of IoT technology is evidenced by the complete flexibility that can be achieved: users can leverage the identical mechanisms within a local network architecture and for communicating with Internet-based services. Cloud providers such as Amazon Web Services and Microsoft Azure have their own IoT message brokers that can be used for communication. The best-known protocols here are currently MQTT (MQ Telemetry Transport) and AMQP (Advanced Message Queuing Protocol), which are both supported by TwinCAT.

The TwinCAT Analytics infrastructure
As previously stated, the IoT interface gives machine manufacturers and end users great freedom when setting up TwinCAT Analytics. Naturally, the TwinCAT Analytics PLC library can be used to analyze the recorded data locally...
TwinCAT Analytics offers numerous application scenarios: data storage and analysis directly on the local controller, and in private networks or in public clouds. The Analytics Server can also analyze a number of machines in one factory. The relevant machine manufacturer or external analyst can access process data in a variety of file formats or fetch the data from TwinCAT Analytics Cloud Storage.

You can alternately install TwinCAT Analytics on a virtual machine. The obvious way of doing this is to use a public cloud. Here, you can flexibly lease and use processor power, storage space and IT infrastructure from vendors such as Microsoft Azure. This greatly simplifies the global connection of machines to the analytics system. Another variant is for machine manufacturers to operate as service providers for their machines and either analyze the generated data in the cloud, or use the cloud only as a “transmission medium” and perform the analysis on a server within their own IT infrastructure. If end users – who are of course interested in high machine availability, high productivity and high product quality – prefer to hire external analysts, they can provide them with the necessary access data for the message broker, the topic architecture and the data description. In this way, a third-party analyst can access the necessary data and offer its customers appropriate services.

**Big data brings big benefits**

TwinCAT Analytics not only provides data using the IoT protocol, it also answers the question of how to use the data. Simply generating enormous amounts of data is not enough, these data volumes also have to be managed. The core element, the TwinCAT Analytics Workbench, makes exactly that possible, providing the ability to analyze data directly online or offline. Online means that the Analytics Workbench uses the IoT communication protocol to subscribe, on the message broker, to the topic corresponding to the machine that is to be analyzed. Offline is an option if the machine has previously stored its data using Beckhoff Cloud Storage. The Cloud Storage facility integrates itself seamlessly into all the variants of the previously described Analytics infrastructure, both in the cloud and in a local IT network environment. The Workbench can then access this historical data and analyze it.
The TwinCAT Analytics Workbench

TwinCAT Analytics Workbench is based on a TwinCAT runtime system that can be configured and programmed using the TwinCAT Engineering Environment. The big advantage is that machine manufacturers do not need to make any changes when switching between the programming environment for the controller and the environment of the analysis software. They can directly apply their years of programming expertise when using the Workbench. This makes it very easy to implement their own analysis algorithms, reuse algorithms previously used for different machines, or alternatively, to use algorithms from the TwinCAT Analytics PLC library. This incorporates modules for counting flanks, analyzing maximum and minimum values, evaluating the timing of machine cycles, and calculating the energy consumption per unit time of a selected component.

Particularly when evaluating the timing of machine cycles, it is useful to identify the shortest, longest and average runtimes. This enables you to recognize potential optimizations or to derive indicators for predictive maintenance. For example, a status analysis can easily determine whether a rotating milling head is frequently stationary, running with speed a, b or c, or is in an error state. Such results can be clearly displayed in a histogram, which is why the familiar TwinCAT Charting Tool, “TwinCAT Scope” is such a crucial feature of Analytics Workbench. This particularly applies to interactions with the Analytics Configurator that is also embedded in the TwinCAT engineering environment. It means that you can compile a post-scope configuration for previously recorded data in order to get a fresh graphical display of the data curves.

The Analytics Configurator

For viewing data, the Analytics Configurator already uses the same algorithms that are used in the Analytics library. The data streams from the selected periods are analyzed in the Configurator and displayed directly. Significant values obtained in this way can easily be dragged-and-dropped into the charting interface of TwinCAT Scope. Scope then automatically navigates to the corresponding locations in order to graphically illustrate their relation to other signals. This makes it much easier to locate the needle in the “big data haystack”. It also markedly simplifies engineering using the Analytics Configurator. Since all algorithms come from the same source, you can take the configuration that was set up in the Configurator, together with all the selected variables and their corresponding limit values, and feed it into the PLC. This enables switching from offline analysis to online analysis using data streamed from the cloud.

The TwinCAT Analytics Workbench Base

The functionality described here refers to the TwinCAT Analytics Workbench Base. This incorporates a TwinCAT PLC runtime system, the Analytics PLC library, an IoT connection for streaming data, the Analytics Configurator and ScopeView Professional. The Workbench can also be extended by installing packages for Condition Monitoring, C++ and MATLAB®/Simulink®. In particular, integrating MATLAB®/Simulink® into the TwinCAT runtime system offers comprehensive access to useful toolboxes that answer tough analytical questions. For example, one such toolbox deals with machine learning and optimization.

In addition to the dedicated extensions of TwinCAT Analytics, other TwinCAT standard tools can also be used. The TwinCAT Database Server can store online and offline data in a variety of databases. An Analytics system can also be supplied with data using the widely used automation protocol, OPC UA. In addition, Beckhoff provides converters from OPC UA to IoT protocols in order to give, for example, third-party controllers access to analysis functions. Another very important solution is TwinCAT 3 HMI, which enables you to design intuitive dashboards based on HTML5 for the Analytics Workbench. This creates an Analysis Cockpit that can then be used to display all the results for a given machine or a number of machines. A hierarchical structure makes it possible to display much deeper levels of detail.
The cloud dissolves the conventional hierarchy of communication architectures.

Forward-looking automation with TwinCAT Analytics
Industrie 4.0 and IoT technologies, and particularly the use of clouds, are increasingly dissolving the hierarchies of conventional communication architectures. All network nodes, from real-time field devices to ERP systems, can now communicate with each other. TwinCAT Analytics suits this trend extremely well, by incorporating not just a single product, but a complete solution. The IoT communication protocols used handle the data transport and give the infrastructure maximum flexibility. The Analytics Workbench itself takes over machine-related evaluations, visualizations and pre-processing of data, as well as long-term database storage. Extended data analysis and machine learning for the purpose of machine optimization can be implemented in TwinCAT through the seamless integration of MATLAB®/Simulink® or other cloud services accessible via IoT protocols. Analytics Workbench makes all of these functions available and is itself directly integrated into the familiar TwinCAT environment in Microsoft Visual Studio®. This robust analysis of machine data serves as a key factor for numerous new business models, as well as for future-proof and efficiency-optimized automation.

Further information:
www.beckhoff.com/iot
www.beckhoff.com/twincat-industrie40
EtherCAT and high-speed automation for register control

Exceptional precision and flexibility

How do you modernize a register controller for web printing machines that has been setting standards in terms of performance for nearly 20 years already? BST eltromat International GmbH, a global market leader in high-quality optical quality measuring and monitoring systems for inline processes, was faced with this difficult question. New requirements now need to be fulfilled due to the changing production and automation environment in the printing industry. It quickly became clear that only a change from the proprietary solution to an open one – implemented with PC control, EtherCAT and XFC technology from Beckhoff – would make the desired precision, flexibility and communication capability possible.

Electronic register controllers are indispensable in web printing for the permanent and program-controlled monitoring of the register. This is in order to synchronize the fields of the printing machine and to print the colors of the individual printing units precisely on top of one another. The corresponding BST eltromat controllers from the “register” product range are the result of many years of development and intensive optimizations based on the needs of the printer. They were developed consistently for the requirements of the most diverse areas of application in web printing – for gravure, flexo, offset and screen printers for inline or offline processes.

The current generation of register controllers – the regi star 20 – is equipped for the detection of print marks with fiber-optic sensor heads or CCD matrix cameras. They ensure the complete detection and measurement of highly complex printing marks even at speeds of up to 1000 m/min. Standardized or individually created printing marks are detected precisely, automatically and with positioning of the measuring window – independent of their parameters such as arrangement, geometry, contrast or order at the edge of the printing web within defined zones or at freely-selectable positions in the print images. The entire operation is menu-guided; all status messages are displayed in plain text. In the event of fluctuations of the web tension and the resulting register deviations, the patented accelerator permanently ensures optimal controller behavior. Even register errors, such as those that can result from roll changes, splices or incompletely printed register marks, are automatically registered and accounted for in the controller behavior.

Impressively precise and failure-proof …

From the complexity of the tasks described, one can already imagine the height of the demands placed on the register controller. This is made clear by the following performance characteristics, as explained by Dipl.-Ing. Dieter Jochmann, Product Manager at BST eltromat: “The local acquisition of the measured values with a precision in the range of 5 μm places high demands in particular on the accuracy and synchronization of the distributed clocks. This must lie in the region of 100 ns and is therefore in the high-end area. The cycle time is around 1 ms and does not fully exhaust the performance capability of the TwinCAT PLC.” The number of networked EtherCAT devices is around 150 to 200 I/O terminals and up to forty optical sensors (register mark sensors developed by BST eltromat).

The replacement of the previous proprietary and completely in-house developed register controller generation had less to do with the efficiency or measurement accuracy, because this was also achieved before, albeit via individually wired devices instead of by bus communication. Only the cycle time of the controller was around 8 ms slower than the new version. In addition to this, the old system was developed at the beginning of the 1990s and had thus been on the market for a very long time and was above all extremely failure-proof. BST eltromat Product Manager Dipl.-Ing. Volker Reinholdt also considers this reliability to be a very important success factor, which also had to be achieved by the successor model regi star 20: “The reliability of the old system was really exorbitant, and in two ways at that: not only stochastic failures, but also lifetime. Our register controller is famous for never failing.” So why redevelop it and change to an open control technology at all? Dieter Jochmann says: The architecture was very much tailored to the special task and was still many years old; that is to say, it no longer fit into the modern automation environment. At the end of the day, we are suppliers to printing machine manufacturers who are naturally also using bus systems to an increasing extent. Their integration would have required a great deal of development expenditure.”

Volker Reinholdt adds: “Apart from the improved communication options, we profit from significantly increased flexibility; that is to say, applications can be changed today very much faster and with less expenditure.

In addition to that, more and more of the old components were being discontinued and support expenditure had thus risen enormously. However, our customers expect the long-term guarantees from us that they are used to.”

… and now also open …

Due to the changing requirements, BST eltromat was faced with the decision of whether to develop a proprietary solution entirely in-house, or to employ open standards. According to Volker Reinholdt this decision became clear relatively quickly: “We no longer wanted to develop all of the computer cards ourselves, but rather to concentrate on our core competencies; in other words, the actual ‘register control’ application. At the end of the day, PC technology is advancing continuously and rapidly. Proprietary developments would therefore have been too complex and not profitable for small series.” BST eltromat had more difficulty with the decision regarding the operating system to be used on the Industrial PC – a Linux derivative with real-time extension or a Windows platform with appropriate software automation components. Ultimately the expenditure to be expected with a change of technology proved to be decisive: The use of Linux would have entailed the proprietary development of a complete framework. The goal was therefore to base the development on a stable and open platform and in this way to profit without great expenditure from the simple integration of arbitrary I/O hardware or of fieldbuses without additional drivers and to be extremely flexible in the
The adaptive RGB register mark sensor works with extreme precision and also has optical Ex-approval.
integration of new functions. Volker Reinholdt sees another advantage of the Windows-based software PLC: “A further argument was the short time to market. With Linux you are dependent on someone getting around to developing a driver for your hardware at sometime or another. There is usually no such uncertainty in terms of time with Windows operating systems.” Dieter Jochmann also confirms that the decision made at that time was absolutely correct: “So far we have had no disadvantages from the use of Windows and the TwinCAT PLC software running on it. And even the original wish to program according to completely object-oriented principles in C/C++ in addition to the classic IEC 61131-3 PLC programming languages will shortly be possible to realize with TwinCAT 3 automation software from Beckhoff – if our developers still want to do so at all following the good experiences we have had with the PLC programming.”

On the other hand, the decision in favor of EtherCAT as the bus system was an easy one to make for the BST eltromat experts: at the end of 2006/ beginning of 2007, the few Ethernet-based bus systems available at that time were evaluated, with the result that only EtherCAT could provide the necessary performance. Volker Reinholdt summarizes: “10 years ago, many were talking about ‘real-time Ethernet,’ but only Beckhoff could actually offer what we wanted — namely the synchronization of the distributed clocks in the 100 ns range.” The mode of operation of the ‘Distributed Clocks’ — a component of the extremely fast XFC technology (eXtreme Fast Control) — is described by Beckhoff sales employee Stefan Sieber: “If we consider a normal, discrete control loop, then the measurement of an actual value is performed at a certain time, the result is delivered to the controller, the reaction is calculated and its result is communicated to the set value output unit and output to the process. For many control processes a strict determinism of this sequence is sufficient. The controlled system determines the necessary speed of the control process. Usually, dead times occurring in controllers, the controlled system, actuating and measuring units are taken into account accordingly in the design of the controller or they can perhaps be compensated. These procedures are basic principles of control technology and have, of course, been standard for many years under TwinCAT. Additionally for the register control, the print marks detected by the print mark sensors must be matched to the high-precision angular positions of the printing units in order to then determine the differences between the positions of the print marks. The necessary temporal exactness for the print marks and detection of the positions of the printing units is supported by high-precision clocks in the I/O components. The EtherCAT devices each have their own local clocks, which are constantly synchronized with one another by EtherCAT. Differences in the absolute time of the EtherCAT devices concerned are compensated, so that the maximum deviation of all distributed clocks in the system is always less than 100 ns.”

After the decision had been taken for an open, Windows-based solution, this had to be physically implemented at BST eltromat. For the developers in particular, who were used to working in an embedded controller world, the step to a PLC was first of all strange and by all means subject to some preconceptions. However, the initial skepticism has quickly dissolved thanks to the considerable advantages, i.e. a stable environment or framework, easily
integrable peripheral hardware and extensive diagnostic tools. The corresponding knowhow had to be acquired very quickly within the running time of the project, however, which is why BST eltromat pursued a two-pronged strategy: first of all a one-week in-house training course was held, and subsequently a Beckhoff technician was integrated into the development team for four weeks – a very short time, but an indication of the simple-to-handle automation technology on the one hand and of the efficient support by Beckhoff on the other. In this manner it was possible to develop the new register controller from the preliminary investigations to the first system running on a production machine in just one year. Volker Reinholdt comments on this achievement as follows: “Taking the approximately halved time to market as a basis, one can assume that the development costs were around 50 % lower. For a proprietary system we would have spent twice as long developing it or we would have had to invest in additional personnel.” He also describes the controllable development progress as a further very important advantage: “This is only possible with the open system. If you develop a proprietary system, which means you are forced to develop the hardware and software separately from one another, then the two can only be tested together at the end. This nearly always leads to redesigns and/or changes of code. On the basis of PC technology, however, the software code can always be verified with the existing hardware. That was an essential element for development security.”

… flexibly and easily integrable
The following Beckhoff components form the basis for the flexibility and the capability of communication to the automation environment achieved by standard technology:

- C69xx Industrial PC with TwinCAT software for register control or print mark control,
- IEC 61131-3-compatible TwinCAT PLC (software PLC),
- EtherCAT Terminals with standard and XFC technology

The decisive success factor for the project was the fast integration of the EtherCAT interface into the optical sensor solution developed by BST eltromat. Stefan Sieber explains: “The optical sensor from BST eltromat has an EtherCAT communication ASIC, which uses the function of the Distributed Clocks. This is supplemented from our side by the ELS101 Incremental Encoder Terminal, into whose standard functions we have incorporated special requirements from BST eltromat.”

Thanks to this powerful standard technology, the BST eltromat developers were able to concentrate all the more on their core competency, e.g. the realization of the optical, adaptive register mark sensor. This was completely developed from the optics through to the integration of the EtherCAT chip and detects both lateral and longitudinal register deviations, wherein it can also detect extremely low-contrast and metallized colors as well as transparent lacquers. The sensor – with optical Ex-approval – analyzes the chromatic spectrum of the light reflected by the web in order to enable the reliable detection of all register marks automatically. Thanks to the large depth of focus of the fiber optics, the user need change neither the signal amplification nor the scanning angle – the reliable detection of the marks is therefore an absolutely intervention-free procedure. With its fully automatic sampling technology, the sensor designed for the regi_star supports the single-head measurement process patented by BST eltromat. This technology enables both sequential control for a fast production start and standard color control for the best possible production quality. A maximum reduction in waste and costs is achieved by the process-dependent automatic changeover between sequential and standard color control or by the use of the different measurement and control procedures in any combination.

Apart from the technological advantages of the color sensor – according to Dieter Jochmann – the higher system flexibility also has a considerable effect: “What we still very much appreciate with Beckhoff is the fact that you can reach all major fieldbuses available on the market via a gateway terminal. There is a great advantage in this for us, since our customers use the most diverse automation technologies and are thus constantly requesting us to provide special interfaces. The system is also flexible with regard to the structure of its hardware; that is to say, some customers wish to accommodate the I/O terminals directly in the associated printing unit, while others want to house all terminals together in a separate control cabinet. We couldn’t have provided that previously.” Volker Reinholdt adds: “In addition to that, we can now thanks to the scalable automation system; in other words, the customer only needs to buy what is really necessary and besides that they have better options to modularize and standardize the printing machine.”

In the meantime BST eltromat has sold over hundred of regi_star 20 units, the majority of which are already in operation. The system has worked stably in many different forms from the prototype onwards. Due in particular to its good integration in the automation environment and its modularity, BST eltromat has been able to reduce manufacturing costs compared to the predecessor system and has passed this advantage on to its customers. This is surely not just a short-term success, since the flexible hardware architecture of the regi_star 20 allow the integration of further functions at any time, and a unique intelligent link between register control and other product areas has been created.

BST eltromat International GmbH www.bst-international.com
The OilPainter is a fully automated picture painting machine that produces images with acrylic paints in a post-impressionist style. It can paint a Mona Lisa in the style of van Gogh or a picture of Audrey Hepburn that looks like it was created by Andy Warhol. The first production-ready model of the painting robot is currently located in a former print shop in Zollikerberg near Zurich in Switzerland, but will soon produce one-of-a-kind paintings for a large furniture retailer, among other clients.

"To create these unique works of art, the data for the motif to be painted must be provided to the controller in a vectorized, pre-programmed form. That way, the machine knows each brushstroke before it even begins painting," explains Patric Lüthi, the CEO of OilPainter Ltd. in Zurich. "When the robot paints, it follows the program stroke-by-stroke with 11 different brush widths, which in turn can be positioned at any angle. By dividing the image into X/Y axes and the R-axis as the rotational brush angle, any stroke can be executed with any brush width. However, unlike a human painter, the OilPainter can rotate the R-axis continuously, for example, to paint a complete spiral without having to lift the brush or to generate a calligraphic work of art."

**Numerically controlled servo technology for high-precision movements**

When the machine paints, the five main axes provide the motion and the five auxiliary axes mix the colors. The three main axes (X, Y and R) must be perfectly synchronized at all times. The Z-axis is governed by the height profile of the canvas and the support table. The fifth main axis controls the brush position, which can be synchronized or non-synchronized with the R-axis.

The OilPainter is controlled via TwinCAT NC I software, as Patric Lüthi explains: "TwinCAT NC I controls the three path axes and the five auxiliary axes. In addition, the jet axis is linked via a master-slave axis, while the Z-axis is safety-
controlled with a separate process. The paint is applied with high-precision, medical-grade pumps, whose auxiliary axes move simultaneously with the three main axes. The pumps, in turn, are driven via three EL7342 2-channel DC motor output stages. The system generates any color in a mixing chamber just ahead of the brush, proportionally with the pumps and in perfect synchronization with the motion speed – even during acceleration or deceleration.

The X- and Y-axes are driven by Beckhoff AM80xx servomotors. The motor for the X-axis is flange-mounted to the axis, utilizing an angular gear with shaft feedthrough and driving two belts. “This way, we can use a standard motor that is mounted perpendicularly to the axis,” Patric Lüthi adds. “These servomotors are controlled via AX512S and AX5118 1-channel Servo Drives, respectively, and we leverage this control technology to support fast and highly-dynamic positioning tasks.” The Z- and R-axes are controlled via AM3112 servomotors, featuring maximum torque yield, high dynamics and high positioning accuracy. They are designed for use with compact EL7201 servo terminal. In fact, the OilPainter uses the high-speed EtherCAT industrial Ethernet protocol for all communication tasks. With a cycle time of 1 millisecond, the controller checks whether all axes are operating synchronously 1,000 times per second.

Applying colors correctly takes practice – even for a robot

According to Patric Lüthi, the technical challenges are huge when it comes to the correct application of acrylic paints: “The color flow must be perfectly coordinated with each brushstroke. In addition, the right color tone must be available instantly without any premixing. That’s why we place the high-viscosity paint under pressure so that it can be pushed to the pumps through hoses. The pumps, in turn, operate with low pressure so that the color can flow smoothly from the brushes without splattering.”

The palette of the OilPainter consists of five basic colors: cyan, magenta, yellow, black (K) and white. “This is a basic difference when compared with color handling by inkjet printers, which rasterize the image in CMYK. We don’t rasterize, which is why we also have white as a basic color and for mixing pastels and greys. Normally, you can produce black with CMY, but it’s actually more of a dark-brownish black. That’s why the software adds black. We create greys from black and white, with the mixing ratios determined by the color’s coverage as well as the quantity and size of the pigments,” summarizes Patric Lüthi about the application requirements placed on the machine’s control technology.

High flexibility through library of functions

The degree of digitization in the final OilPainter artwork depends on the picture’s complexity and the desired results. “The user must determine which brush width and color you want to use. After all, we don’t merely want to copy the original painter’s style – which is why we have developed our own logic,” explains Patric Lüthi. “If you want to paint the reflection of sunlight on a face, for example, the system must know which brush should apply the white color at which point. The result is impressionist. If you permit only straight brushstrokes, the picture looks like it was painted with a putty knife. Alternately, if you permit only points, the finished art is close to pointillism. The time it takes to produce a painting depends on the number of brushstrokes. For example, if you have 10,000 strokes with each taking one second, a picture can take several hours.”

All brushstrokes are stored in a Visual Basic interface. With its numerous library functions, TwinCAT uses this information to generate the various painting options. “The controller translates the data into CNC commands. The GUI generates the G-code and transfers each complete brushstroke to TwinCAT for execution. A complete picture requires thousands of brushstrokes, and if you were to convert all brushstrokes into their waypoints in a single step, you would wind up with a huge G-file, which would overtax the computer’s RAM and make interruptions impossible,” explains Patric Lüthi. “However, we must be able to clean the system between color changes or wait until parts of the picture have dried to continue painting.”

Although a painting robot seems quite exotic at first glance, the solutions can be transferred to other industries, which is why OilPainter Ltd. has already received inquiries to develop solutions for other compounding challenges, again featuring Beckhoff control solutions.
PC-based labeling and marking solutions from C3 can be operated from web-capable devices such as smartphones and tablets.
Smart Identity System connects ERP and shop floor

The development of innovative labeling and marking solutions is one of the main undertakings of C³ Corporation. Based in Appleton, Wisconsin, C³ recognized at an early stage that intelligent track-and-trace is the key to intelligent manufacturing. Equipped with PC-based control technology, the Smart Identity System developed by C³ provides comprehensive remote connectivity, enabling users to access applications via web-capable devices like smartphones and tablets.

C³ track-and-trace systems are used in many industries like foam and urethane production, the paper and packaging industry, the food and beverage industry, as well as in the finished metal products industry. “We work very closely with our customers. We want to understand the entire operation from the shop floor to the top management level and everything in-between. This enables us to eliminate bottlenecks and make the whole operation more efficient,” explains Joe Van De Hey, the CEO of C³.

With the company’s Smart Identity System for marking products with data-intensive labels, C³ has managed to introduce a new development in the field of integration services. “Our system gives customers an accurate overview of their operation’s throughput rates and effectiveness. Via remote access they can use any web-capable device to issue commands, change templates and labels, run diagnostics and access data,” explains C³ application and database engineer, Drew Demerath. “The openness of the PC Control platform also allows us to adapt our labeling and marking solution to the customer’s specific requirements.”

**PC-based control: Integrated, highly-connected control platform**

The control platform of the Smart Identity System consists of a Beckhoff CX2020 Embedded PC with a 1.4 GHz Intel® Celeron® CPU, TwinCAT 3 automation software, and EtherCAT as the real-time communication system. “The Embedded PC, with its directly connected EtherCAT I/O terminals, allows us to design the system with great flexibility. This is a huge benefit, because all our applications and installations are customer-specific. The PC-based control solution also enables optimal vertical and horizontal integration. For example, linking to an ERP system is just as easy to implement as it is cost-effective,” adds Joe Van De Hey. “The controller’s connectivity allows you to link it to the
The Smart Identity System from C3 features extensive connectivity. Users can issue commands, run diagnostics, change templates and labels, and access data from any web-capable device.
The Smart Identity System uses a CX2020 Embedded PC running TwinCAT 3 automation software as its control platform and Windows 7 as the operating system.

Cloud and access it via mobile devices from anywhere as long as the customer's network is VPN-capable. C³ has also begun to implement OPC UA so that users of Smart Identity Systems can see the same data at the same time with built-in security and data encryption.

"Based on PC-based control technology we implemented a web server, a comprehensive database and a controller in a single device," says Drew Demerath. "Conventional systems can’t compete with this solution because they require multiple hardware layers or separate devices. With PC Control we simply add more software layers, combine everything in a single hardware device, and sell the solution as an all-in-one, turnkey package."

**Automation technology and IT convergence via TwinCAT 3**

TwinCAT 3 plays an important role in the labeling and marking solutions from C³. In addition to the standard programming languages for automation applications, TwinCAT 3 offers a wide range of IT engineering tools. "The development software, the easy installation of web servers and a series of new software tools give us many options to further advance the functionality of our Smart Identity Systems," explains Joe Van De Hey. "As a result, we can embed many functions at no additional cost into the PC-based software platform, which makes the work of our developers considerably easier."

The TwinCAT 3 software libraries make it possible to implement one or more TCP/IP servers and/or TCP/IP clients within the TwinCAT 3 controller. The controller variables and/or the direct values from the EtherCAT I/O system can be recorded and saved in databases cyclically or in an event-driven manner. "With the TwinCAT 3 Database Server, C³ was able to significantly expand the history tracking and trend analysis functionalities," says Demerath. "We can see all the labels and the markings throughout a line, and it is rather easy to view what a facility has produced by the day, month or year."

C³ uses a variety of digital EtherCAT I/O terminals to connect sensors, scales, scanners and other field devices. EP6652-0010 EtherNet/IP slave terminals handle the communication with other industrial Ethernet systems. They provide a direct link to EtherNet/IP devices in C³ applications and return their data via EtherCAT.

**Power through intellectual property**

C³ recently installed the new PC-based Smart Identity System for a highly automated national dairy processor client. "This company can now gather data about its recipes and improve their traceability," says Drew Demerath. In the previous system, the main PLC sent requests to a computer, which then sent the print commands to the label printer. The issue was time: Since a single computer controlled all the labelers, a boxed product would frequently be missing a label because it was not printed on time. Consequently, the product had to be sent back through the system to be properly labeled. "EtherCAT allowed us to increase the labeling speed significantly," says Joe Van De Hey. "The real-time communication system makes sure that all labels are correctly printed by the time each package arrives for final processing." It also gives the company access to its entire production history. Another advantage of the PC-based solution is the system’s source code protection, says the CEO: "This solution allows the customer to protect valuable intellectual property."

The hot-connect capability of EtherCAT also made it much easier to switch out print engines and consumables. "These processes could take four hours or more on the plant floor if you include the IT department’s involvement with the ERP systems. With PC-based control and EtherCAT, it takes one person just about half an hour now," reports Joe Van De Hey.

Further information:

www.c3ingenuity.com
www.beckhoffautomation.com
OCTANT Siebdruck GmbH, the family-run company based in Bielefeld, Germany, specializes in the UV-screen printing of plastic items. Printed panels for domestic devices are delivered “just-in-time” from a fully automatic screen printing line, directly to the customer’s ongoing production: the quantity ordered is delivered at exactly the right time, sorted according to the assembly line and the manufacturing order.

Customer know-how secured

In spite of preventive maintenance, the reliability of the PLC-controlled screen printing line at OCTANT, installed in the 1990s, was continuing to fall. As controller spare parts were no longer available on the open market, the company decided to retrofit the plant control system, under one condition: The work had to be completed during the end-customers’ three-week company holiday. As Stefanie Neuhaus, Managing Partner at OCTANT, explained, “We work in three shifts to print assemblies on the screen printing line. We deliver the assemblies about 36 hours in advance, directly to the end-customer’s production facility.”

OCTANT’s Managing Director Wolfram Meyer added that, “The competitive pressure in our industry and the need to secure our own know-how both played a role in the decision between retrofitting and a new installation. The method we use is, we believe, unique to the whole world. We use UV flash drying in our compact plant, while our competitors use a long tunnel to dry the ink. This makes OCTANT much more flexible. We also benefit from very short reaction times whenever changes are made.”

Skilled engineering team provides the assist

OCTANT looked for a partner for this retrofit who could handle everything from project planning through to production start-up, and decided in favor of the Applications Engineering Department at Beckhoff Germany. As an independent department employing about 150 staff, the team has profound expertise in this sector, and offers complete solutions for almost any application, from machine construction to wind turbines. This expert team can provide support to Beckhoff customer applications throughout every location. David Derksen, Project Coor-

In order to ensure the reliability of their screen printing line, OCTANT Siebdruck GmbH decided to initiate a retrofit. This had three advantages over a new installation: securing long term production at the company’s Bielefeld, Germany site, protection of the company’s own know-how and protecting the investments already made. The short amount of time available for the retrofit was among the challenges faced: An engineering team from Beckhoff had only three weeks to help OCTANT convert the PLC-controlled screen printing line, built in the age of parallel wiring, to modern, PC-based and EtherCAT-based control technology.

Flexible working time patterns enabled production-free periods to be considered when planning the retrofit. To achieve optimum implementation at OCTANT, the obsolete plant components were dismantled over the weekend. This increased important time reserves for installation and commissioning.
The Beckhoff Engineering Team, describes the special challenge of this project: “This controller retrofit demanded particularly precise project planning and implementation if the specified time window of just three weeks was to be satisfied. The customized complete solutions from our in-house development gave us important time reserves before the start of production, and these were needed for the integration of third-party systems.”

Centralized, real-time control combines all functions

Originally, the operating panels at each of the four printing stations constituted a self-contained control environment with dedicated I/O components. This proprietary signal transmission arrangement was modernized: The control cabinet for the screen printing line, with a C6920 Industrial PC (IPC) and TwinCAT NC PTP software, constitutes the central controller. A 15-inch CP6902 “Economy” Control Panel is fitted into the front for central, visual component tracking. The compact C6920 IPC needs only three RJ45 sockets in addition to the DVI connector to connect to the peripheral equipment: One for an EtherCAT line, one for a remote servicing interface via Ethernet, and one for a switch that distributes signals from the control computer to Ethernet operating panels on the printing units.

In each printing unit, an EK1100 EtherCAT Coupler acts as a decentralized I/O station, combining all the signals that were originally wired in parallel. Starting from the control cabinet, this EtherCAT line stretches out over the field level to the servo controllers. The assemblies of the central chain drive and of the individual printing units were replaced with AM3000 synchronous servomotors and AX5000 EtherCAT Servo Drives, all from Beckhoff.

Decentralized operation: Stainless steel control panel

Four CP6607 Ethernet Control Panels with 5.7-inch touch screens and customer-specific displays replaced the previous operating panels. The design of the CP66xx series housing has a new, extra-smooth stainless steel front panel without edges or seams, making it ideal for use in the tough production environment of a screen printing plant. The panel design also avoids deposits of liquid or moisture, simplifies cleaning, and prevents the formation of the kind of persistent soiling that the inks and cleaning fluids used in a printing facility can cause. The buttons and switches on the panel are programmed as TwinCAT network variables. With the help of real-time Ethernet, not much programming is needed to transmit button pushes in real-time.

Substantial refurbishment of the control equipment:
Not just new, but better than ever

Thanks to the open automation equipment from Beckhoff, the retrofit has brought the screen printing line up to 2011 technical standards: From the IPC, through the drive equipment and onto the I/O level, the components are perfectly matched to the existing plant. Only the control for the UV dryer and the sensor equipment used was not part of this substantial upgrade. David Derksen is aware of other aspects of a retrofit: “It is more than just a matter of restoring functionality by utilizing the latest equipment. We have an opportunity to comprehensively optimize the plant and therefore to improve it and increase productivity significantly.” Plant operators were able to provide valuable influence on the project as early as the concept phase because of an analysis of the production process that occurred over several days prior to the retrofit.

Time window successfully met

A large proportion of the components were wired and tested at Beckhoff in advance. The time that this made available was used for intensive, on-the-job-training, involving customer-specific optimizations when getting the plant started. Stefanie Neuhaus is convinced by the result: “The equipment is running much more steadily and smoothly. Not only is it easier to operate, but there has also been a pleasant side-effect: The new drive equipment has markedly lowered the level of noise in the production department.” TwinCAT and the precise regulation of the EtherCAT Servo Drives enable the individual process steps to be better matched to one another now. “During the supervised production start-up, the plain text fault messages were made to be more precise, and the menu control was adjusted so that the plant can now be operated more intuitively. Because this has shortened operators’ reaction times, our productivity has risen and the amount of scrap has fallen,” summarizes Stefanie Neuhaus.

Further Information:
www.octant.de

In screen printing, the ink is spread with a doctor blade through a fabric pattern on to the component to be printed and is hardened by UV-light. OCTANT’s printing line comprises a loading station, four printing units, and a removal unit.