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? eltromat 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 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 latest 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. Volker Reinholdt, Project Manager at 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 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. eltromat Managing Director Dr.-Ing. Johann-Carsten Kipp 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."

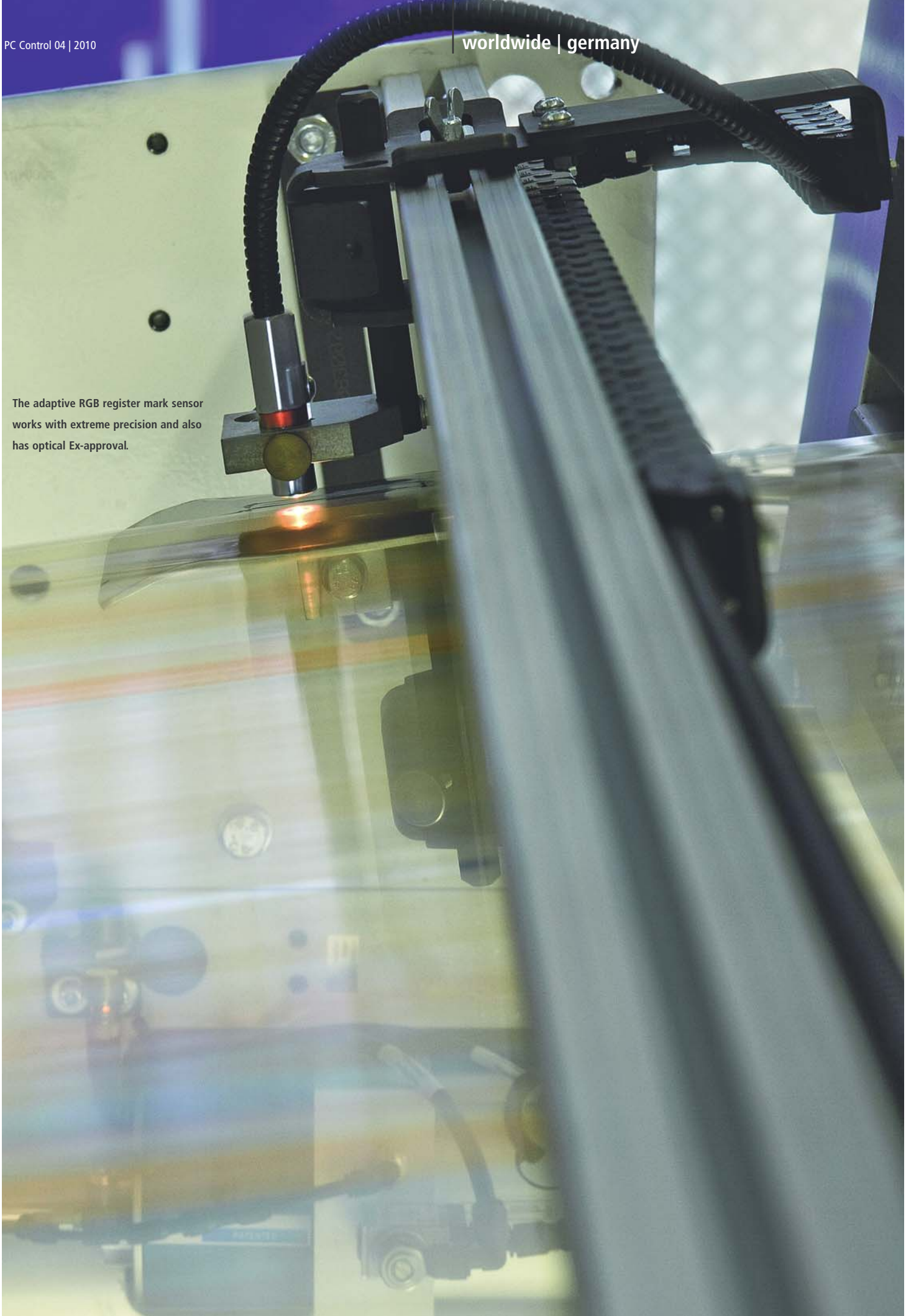
So why redevelop it and change to an open control technology at all? Volker Reinholdt says: The architecture was very much tailored to the special task and was still 20 years old; that is to say, it no longer fit into the modern automation environment. At the end of the day, we are suppliers to printing machine manufacturers who are naturally also using bus systems to an increasing extent. Their integration would have required a great deal of development expenditure."

Dr. Johann-Carsten Kipp 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, 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." 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 integration of new functions. Dr. Johann-Carsten Kipp 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 devel-



The adaptive RGB register mark sensor works with extreme precision and also has optical Ex-approval.

Dr.-Ing. Johann-Carsten Kipp, Managing Director at eltromat GmbH

Dipl.-Ing.Volker Reinholdt, Project Manager Product Development at eltromat

The print marks are detected quickly and precisely thanks to XFC technology from Beckhoff.

oping a driver for your hardware at sometime or another. There is usually no such uncertainty in terms of time with Windows operating systems." Volker Reinholdt 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 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. Dr. Johann-Carsten Kipp summarizes: "Back then, 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 via 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."

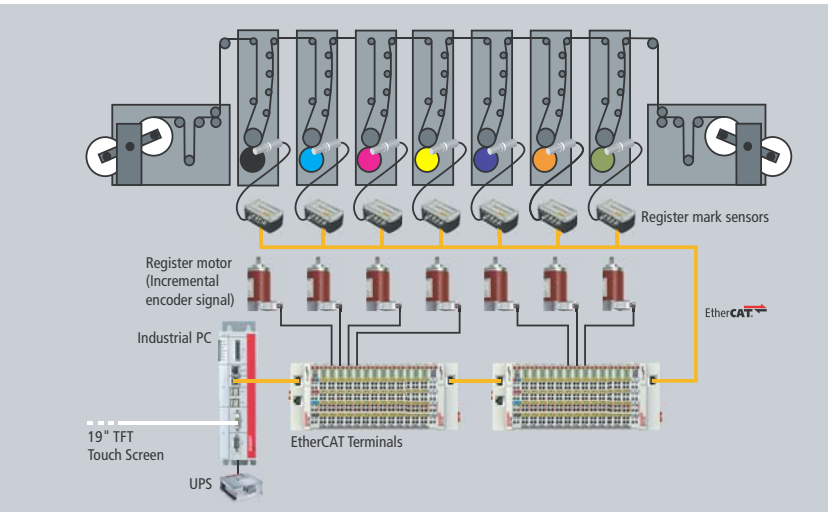
After the decision had been taken for an open, Windows-based solution, this had to be physically implemented at eltromat. For the developers in particular, who were used to working in an embedded controller world, the step to a PLC was first of all strange and by all means subject to some preconceptions. 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 know-how had to be acquired very quickly within the running time of the project, however, which is why 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

Stefan Sieber, Sale, Beckhoff

High-speed with XFC

XFC (eXtreme Fast Control) is based on an optimized control and communication architecture consisting of an Industrial PC, I/O terminals with advanced real-time properties, the EtherCAT high-speed Ethernet system and the TwinCAT automation software. I/O response times < 100 µs can be realized with XFC. This technology opens up new process optimization options for the user. The EtherCAT Distributed Clocks thereby represent a core XFC technology.

www.beckhoff.com/XFC



The structural principle of the register controller

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. Dr. Johann-Carsten Kipp 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,
- C62xx IPC for the eltromat image processing,
- IEC 61131-3-compatible TwinCAT PLC (software PLC),
- EtherCAT Terminals with standard and XFC technology and
- CU20xx Ethernet switches.

The decisive success factor for the project was the fast integration of the EtherCAT interface into the optical sensor solution developed by eltromat. Stefan Sieber explains: "The optical sensor from eltromat has an EtherCAT communication ASIC, which uses the function of the Distributed Clocks. This is supplemented from our side by the EL5101 Incremental Encoder Terminal, into whose standard functions we have incorporated special requirements from eltromat."

Thanks to this powerful standard technology, the 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 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 Volker Reinholdt – 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." Dr. Johann-Carsten Kipp adds: "In addition to that, we can now adapt the register controller much better to OEM applications 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 eltromat has sold over 100 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, 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 allows the integration of further functions at any time, and a unique intelligent link between register control and web monitoring has been created.

Eltromat **www.eltromat.de**