Application Note DK9222-0211-0021
XFC

Time stamp – a snapshot of control technology

This application example describes how, using the Beckhoff XFC technology, the temporal resolution of field signals for the controller is made several times more precise and, in addition, the validity of the process data is released from the PLC cycle. The bases for these characteristics are the fast real-time fieldbus EtherCAT and the time stamping features of the Beckhoff EL1252 and EL2252 digital input and output terminals, whose process data contain the exact time specification of an event in addition to the user data.

Introduction: XFC – eXtreme Fast Control

XFC is a control technology that enables very fast and highly deterministic I/O responses. It includes all hardware and software components involved in control applications:

– optimized I/Os that can pick up signals with high accuracy or initiate tasks,
– EtherCAT as an extremely fast communication network,
– high-performance Industrial PCs as the basis for the control hardware
– TwinCAT, the automation software that links all system components with one another.

Contrary to the original free-running communication links, in which the determinism of the process signals was accordingly inaccurate, the employment of XFC significantly lowers the cycle time and the determinism required for rigorous real-time demands. XFC enables cycle times of 100 µs without sacrificing the centralized intelligence and its high-performance algorithms. XFC also includes additional technologies that not only improve cycle times but also temporal accuracy and resolution. This opens up new possibilities to improve the quality of machines and to shorten reaction times. Measuring tasks, such as preventive maintenance, the monitoring of life cycles or the documentation of parts quality, can all be integrated

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in a simple manner in a central place in the machine controller without requiring external black boxes. XFC technology is completely compatible to existing solutions in all areas and can be used simultaneously on the same hardware and software platform as other control processes such as PLC and motion control, for example.

Validity of process data

Each PLC-based controller works cyclically: it communicates with its environment by receiving input data, processing these on the basis of the calculation specification ('program') and then outputting them to the field as output data. Ideally, the fieldbus cycle can be executed so quickly that refreshed input data are already present at the beginning of the next program cycle. Depending on the requirements, these cycle times vary between 50 μs to over 100 ms, and are dependent on the fieldbus used and the performance of the controller. Independent of the PLC cycle time, the cycle time of the fieldbus must also be taken into account: Not every fieldbus technology available on the market permits synchronous operation of the PLC and fieldbus with low cycle times, so that a further temporal inaccuracy can also arise here.
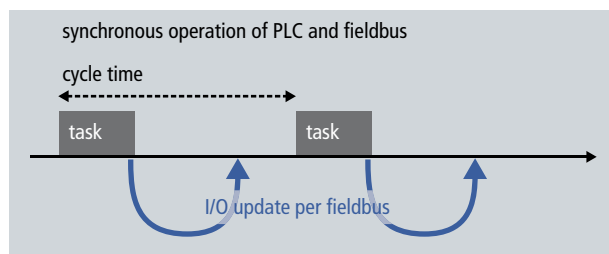

Fig. 1   Synchronous operation

Due to this cyclic orientation, however, an event that occurs in reality at a certain, singular point in time can only be assigned temporally by the PLC in a certain pattern, i.e. the length of the cycle time. If the controller works, for example, with a cycle time of 10 ms, the edge change at the read-in input actually took place 'sometime' within the preceding 10 ms before the I/O update. A more exact assignment than the cycle time resolution of 10 ms is not possible.
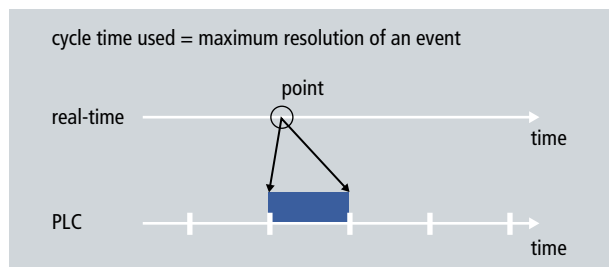

Fig. 2   Temporal relation

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If the temporal assignment is to be more precise, only the cycle time can be reduced by using a 1 ms task instead of a 10 ms one. A temporal classification that is more precise by a factor of 10 is thus possible. This leads to a higher load on the controller and fieldbus and can impair system stability in the case of overloading. Low performance controllers in particular impose limits on this approach. As a positive side effect, the possible minimum reaction time of the controller to external events is thereby shortened, but that is not the main subject of this application example.
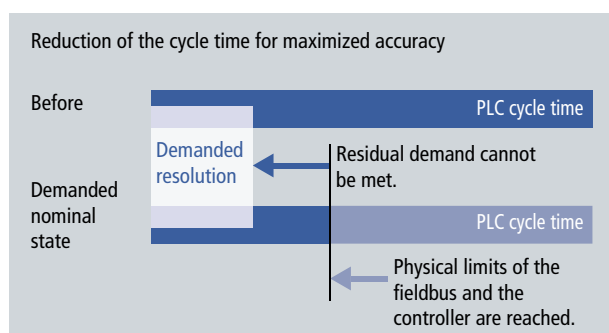

Fig. 3   Reduction of the cycle time

Time-stamped process data with an application-wide, uniform timebase

A further approach to the refinement of the temporal resolution is the use of time-stamped process data under EtherCAT with XFC. The special "Timestamp" XFC terminals for the EtherCAT terminal system from Beckhoff pass not only the event on to the controller via the fieldbus, but also add a time specification in the form of a time stamp. This time specification can be used in order to establish the exact temporal relationship between event and reaction inside the controller. The basis for the use of the time stamp is an application-wide, uniform timebase, which is guaranteed by the EtherCAT Distributed Clock mechanism.
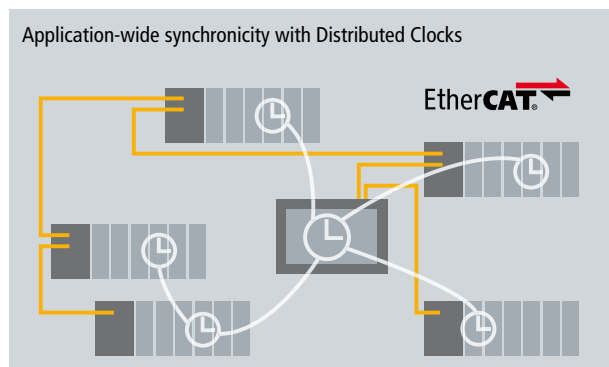

Fig. 4   Application-wide synchronicity

The various segments and devices in an EtherCAT network are synchronized via Distributed Clocks. The micro-delays in the protocol runtime are calculated and the system times of the individual devices are corrected accordingly. This approach results

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in the identical system time being present in the entire network. In addition, the controller/PLC is also synchronized, as a result of which the fieldbus clock with the I/O update is synchronous to the PLC.

The exact temporal assignment of the events takes place on this uniform timebase. The process data no longer consist only of user data; they additionally have a time stamp containing the concrete time of the event. The time stamp is a 64-bit value with a resolution of 1 ns, which enables a significantly more detailed temporal reference of the process data and releases the process information from the PLC cycle. With typical plant sizes, the performance of EtherCAT is so high that signals collected from the field are available to the controller even before a new computing cycle is started. Hence, a short reaction time is already possible in the next cycle.

Influence on input signals

Due to this time stamp principle, event recognition is released from the coarse pattern of the cycle clock and can be resolved with the much finer pattern of 1 ns without increasing the system load.
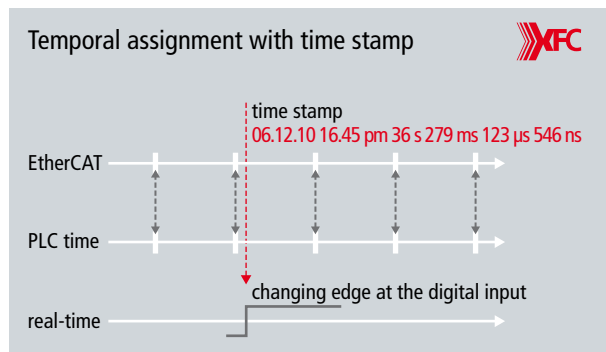

Fig. 5   Temporal classification by time stamp

Influence on output signals

The time stamp principle is also used to trigger events, since the identical criteria of the temporal assignment exist here and the switching of output signals is also released from the rigid pattern of the cycle time. If a digital output is to be activated at a defined time X, in order to trigger a cutting procedure on a paper web, for example, an appropriate time stamp is set for the digital output. The time at which the cutter must be activated is calculated from the temporal relationship between the transport speed of the paper web and the length of the piece to be cut.

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Time stamp terminals from Beckhoff

EL1252 | 2-channel digital input terminal with time stamp
EL2212 | 2-channel digital output terminal 24 V DC with overexcitation
EL2252 | 2-channel digital output terminal with time stamp, tri-state

In addition to the EtherCAT Terminals, Beckhoff also offers all required components for a control solution that enables very fast and extremely deterministic reactions. XFC includes all hardware and software components involved in control applications: optimized input and output components that can pick up signals with high accuracy or initiate tasks, EtherCAT as the very fast communication network, high-performance Industrial PCs and TwinCAT, the automation software that links all system components.

Practical example | simultaneity

Without the use of a time stamp, it is not possible from the point of view of the CPU to distinguish changes of a signal within a fieldbus cycle or to classify them with a temporal accuracy greater than the time pattern dictated by the fieldbus. Therefore, the simultaneity of events cannot be adequately judged. Thus in fault finding, for example, the time stamps from the various field devices can be compared with one another in order to differentiate the causes of consequential errors.

Practical example | reference signals in test setups and test benches

External high precision clocks, for example the atomic clock of the Physikalisch-Technische Bundesanstalt (Federal Institute of Physics and Metrology) in Braunschweig (Brunswick), Germany, are often used to provide the test setup of a device with a reliable and constant timebase that is valid as a reference measured variable in different series of tests. For simple integration via decentralized I/Os, the time signal is laid as a clock on a digital input terminal with time stamp, e.g. the EL1252 EtherCAT Terminal. Since the EtherCAT Terminals work with the high bandwidth of 100 Mbit/s right into the terminals, the controller of the test setup can fall back on the fed-in time signal and place all events within the system in exact relationship to one another by the Distributed Clocks function. The deterministics arising from this are identical for all measurement series and allow concrete conclusions to be drawn between two different series of measurements.

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Apart from the time-constant measurement of events by the time-stamped process data, actions are also executed at a precisely defined time. Thus, parallel wired peripherals can be eliminated on test and experimental benches by means of not initiating an action directly by a user intervention, but rather by the user 'announcing' it at an exactly defined process data point/time.

The described relations are decisive for test benches in which a volume throughput per unit time is measured.

Fig. 6   Practical time stamp example: calibration to an external reference

– 2-channel digital input terminal with time stamp **www.beckhoff.com/EL1252**
– 2-channel digital output terminal 24 V DC with overexcitation **www.beckhoff.com/EL2212**
– 2-channel digital output terminal with time stamp, tri-state **www.beckhoff.com/EL2252**
– XFC: The new class of Control Performance **www.beckhoff.com/XFC**
– EtherCAT **www.beckhoff.com/EtherCAT**