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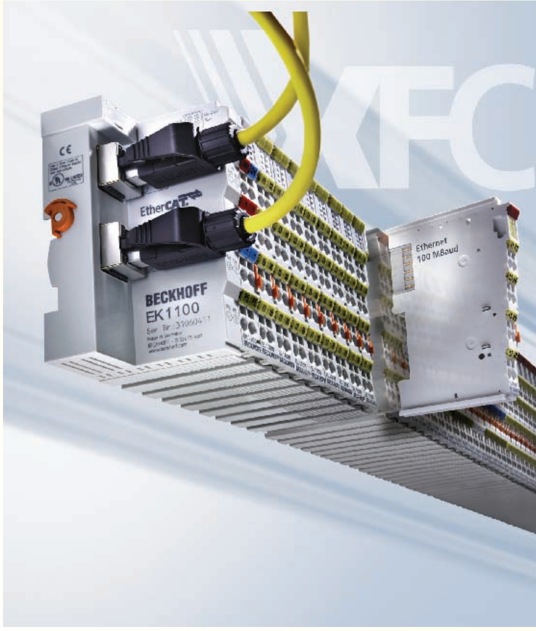
Beckhoff combines several high speed techniques to realise I/O response times of less than 100 microseconds. This opens up new ways to optimise machines processes.

XFC – eXtreme Fast Control Technology



Not long ago, machine control cycle times around 10 to 20 milliseconds were considered state-of-the-art. The main barrier to improvement was the communications interface: it was not synchronised throughout the network and so the determinism associated with responses to process signals was not as accurate as it could be.

High-performance industrial PC controllers and newer, highly synchronised networks enabled a reduction in cycle times by a factor of 10, down to one or two milliseconds. Many special control loops, which were formerly run at decentralised controllers so they could provide fast response, could thus be moved to the central machine controller.

XFC offers a further reduction of response times by a factor of 10. Cycle times of 100µs (microseconds) can be realised, without having to give up central intelligence and high-performance algorithms. XFC includes additional technologies to improve time accuracy and resolution.

Users benefit from new options for enhancing the quality of their machines and reducing response times. Measuring tasks such as preventive maintenance, monitoring idle times, or documentation of parts quality can be integrated in the machine control without costly special devices.

In a practical automation solution, not everything has to be extremely fast and accurate—many tasks can still be handled with 'normal' solutions. But certain tasks in machine operation benefit from high-speed deterministic control. For example, Chris Choi, of the Canadian-based company Husky Injection Molding, describes how his machines benefit from EtherCAT's faster communication. He cited an application where the network decreased part weight variations to less than 0.3%, which saved his customer $182,000 per year.

XFC technology is compatible with existing solutions and can be used simultaneously with the same hardware and software.

Shifting accuracy to the I/O level

Very fast physical responses require suitably short control cycle times in the control system. A response can only take place once the control system has detected and processed an event.

The traditional approach for achieving cycle times in the 100µs range relies on special dedicated controllers with their own directly controlled I/Os. This approach has clear disadvantages, because separate controllers have only limited information about the overall system and therefore cannot make higher-level decisions. Re-parameterisation options, such as may be necessary for new devices, are also limited. Another significant disadvantage is the fixed I/O configuration, which generally cannot be expanded.

The basis for XFC's high determinism is in the EtherCAT clocks. All EtherCAT devices have their own local clocks, which are automatically and continuously synchronised with all other clocks via the EtherCAT communication system. Different communication run-times are compensated for, so that the maximum deviation between all clocks is generally less than 100 nanoseconds (0.1µs). The current time of the distributed clocks is referred to as *system time*, because it is continuously available across the whole system.

In typical control loops, data acquisition occurs at a certain time (input component), the result is transferred to the control system (communication component), the response is calculated (control component), the result is communicated to the set value output module (output component) and then issued to the process (controlled system). XFC promises to do all this in less than 100µs (Figure 1).

The crucial factors for the control process are: minimum response time, deterministic data acquisition (that is, an exact timing calculation must be possible), and a corresponding deterministic set value output. At what point in time the communication and calculation occurs between the input and output is irrelevant, as long as the results are available in the output unit in time for the next output. In other words, great timing precision is required in the I/O components, but not in the communications or the calculation units.

Time stamps and oversampling

XFC introduces two techniques borrowed from the high speed test and measurement world: oversampling, to get a more accurate picture of the input and output signals, and time stamping, to precisely identify the time at which a data sample is taken.

In standard control systems, process data are usually transferred in their respective data format (one bit for a digital value or one word for an analogue value). The temporal relevance of the process record is therefore inherent in the communication cycle during which the record is transferred. However, this also means that the time resolution and accuracy is limited to the communication cycle.

XFC takes advantage of the much greater time resolution of the EtherCAT system clocks to identify input and output data with specific time stamps.

This time stamp—expressed in the ubiquitous EtherCAT system time—enables provision of timing information with significantly higher precision for the process record. Time stamps can be used for inputs, to identify the time of an event occurred, and outputs to give the exact timing of a response.

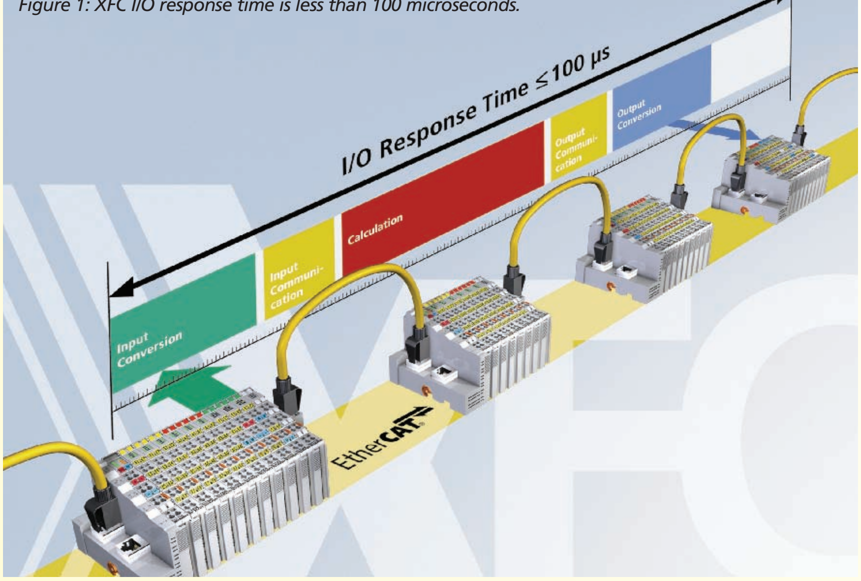
Process data are usually transferred exactly once per communication cycle. Conversely, the time resolution of a process record directly depends on the communication cycle time. Higher time resolution is only possible through a reduction in cycle time—but this has its practical limits. To move beyond this limitation, XFC uses a technique called oversampling.

Oversampling data types enable multiple sampling of a process record within a communication cycle and subsequent (inputs) or prior (outputs) transfer of all data contained in an array. The oversampling factor describes the number of samples within a communication cycle and is therefore a multiple of one. Sampling rates of 200 kHz can easily be achieved, even with moderate communication cycle times. So, if the communications cycle is 10 kHz (100µs) and oversampling is at 200 kHz, you will have an oversampling factor of 20 (Figure 2)

While oversampling does not decrease the I/O response time, it does allow the possibility of evaluating a signal in much higher resolution, for perhaps diagnosis or measurements. Output oversampling can be used to control an output with a higher resolution as the cycle time. So, for complex control algorithms, the resolution and accuracy of the input signals and the possibility to control the output signal in a smoother way will improve the results.

The triggering of the oversampling is performed in the I/O components and is controlled by the local clock, which, because of its high synchronisation (0.1µs) is the same as the global system time. This enables associated time relationships between distributed signals across the whole network.

Figure 1: XFC I/O response time is less than 100 microseconds.



XFC components

Beckhoff's XFC product range is based primarily on high performance industrial personal computers (IPCs) and three major components: EtherCAT fieldbus, EtherCAT I/O terminals, and TwinCAT software.

Modern IPCs are good platforms for XFC. Dual core processors allow the operator interface to run in parallel with the control tasks. Large caches available with modern CPUs are ideal for XFC technology, because fast algorithms run in the cache and can therefore be processed even faster.

An important factor for short XFC cycle times is the fact that the CPU is not burdened with complex process data copying tasks needed by traditional fieldbuses with their dual port RAM-based central boards. EtherCAT process data communication can be handled entirely by the integrated Ethernet controller.

Standard EtherCAT terminals already offer full support for XFC technology. Synchronisation of the I/O conversion with the communication or, more precisely, with the distributed clocks is already standard in EtherCAT and is therefore supported by all terminals.

Newly developed XFC terminals offer additional special features that make them particularly suitable for fast or high-precision applications:

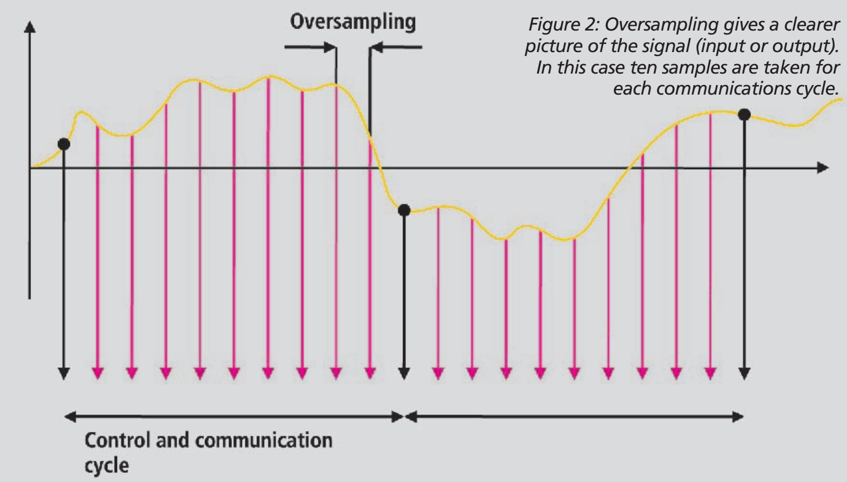


Figure 2: Oversampling gives a clearer picture of the signal (input or output). In this case ten samples are taken for each communications cycle.

- Digital EtherCAT terminals with very short T_{on} /T_{off} times, or analogue terminals with particularly short conversion times;
- EtherCAT terminals with time stamp latching at the exact system time at which digital or analogue events occur. The output of digital or analogue values can occur at exactly predefined times; and
- Terminals with oversampling enable actual value acquisition or set value output with significantly higher resolution than the communication cycle time.

High speed fieldbus

With high communication speed and usable data rates EtherCAT offers the basic prerequisites for XFC. However, speed is not everything. The option of using the bus to exchange several independent process images arranged according to the control application enables parallel application of XFC and standard control technology. The central control system is relieved of time-consuming copying and mapping tasks and can fully utilise the available computing power for the control algorithms.

The distributed EtherCAT clocks that form the time synchronisation backbone of the XFC technologies are available in all communication devices without significant additional effort. The crucial point of XFC is the option of integrating all I/O components directly in the EtherCAT communication, so that no subordinate communication systems (sub bus) are required. In many XFC terminals the A-to-D or D-to-A converter is connected directly to the EtherCAT chip, so that delays are avoided.

Software

The real-time implementation of TwinCAT supports different tasks with different cycle times. Modern industrial PCs can achieve cycle times of 100µs or less without problems. Fieldbuses can be mixed. The associated allocations and communication cycles are optimised according to the fieldbus capabilities.

The EtherCAT implementation in TwinCAT makes full use of the communication system and enables application of several independent time levels. This enables the coexistence of XFC and normal control tasks in the same system, without the XFC requirements becoming a 'bottleneck.'

A new option specially designed for XFC enables inputs to be read during independent communication calls and outputs to be sent directly after the calculation. Due to the speed offered by EtherCAT the inputs are read 'just' before the start of the control tasks, followed by immediate distribution of the outputs. The resulting response times are faster than the fieldbus cycle time in some cases.

Special TwinCAT extensions facilitate handling of the new XFC data types (time stamp and oversampling). PLC blocks enable simple analysis and calculation of the time stamps. The TwinCAT scope can display the data picked up via oversampling according to the allocated oversampling factor and enables precise data analyses. ❖

—Dr.-Ing. Dirk Janssen, Beckhoff Automation, Germany