Application Note DK9322-0210-0017
External clocks

Keywords
DCF77
GPS
IEEE 1588
synchronicity
synchronisation
coordinated sensor detection
simultaneous events
external clock
simultaneity
EL6688
EL6692

Synchronisation levels

This application example explains the levels of synchronisation and their implementation in TwinCAT.

Basic principles: synchronicity levels

Depending upon the plant, application and area, it is necessary to synchronise the individual components to differing degrees. This can range from the simple matching of the components within an I/O strand up to the absolute simultaneity of processes. These processes can take place not only locally within a plant or a production facility, but can also be distributed over a wide area. For example, energy data from transformer stations in the entire network are logged in order to discover the cause of network disturbances and to reconstruct their spreading and effect over time. Synchronisation takes place not only to internal events, but under certain circumstances also to external events. In principle, synchronisation can take place at four levels:

A– worldwide (global)
B– cross-plant over an extensive area (regional)
C– cross-application in the complete system (applicational)
D- locally in the I/O strand (local)

These four levels also span the accuracy classes that can be achieved with the present technical conditions at the individual levels. In principle, synchronicity on the smallest possible time base is not necessarily meaningful for each application. At the local level the synchronicity requirement has been less than 1 ms for several years. – A global synchronicity of the order of milliseconds is used for stock exchange dealings or air traffic control. In order to clarify the criteria for the determination of synchronicity requirements, example applications are listed here for the individual synchronicity levels:

Application Note DK9322-0210-0017

External clocks

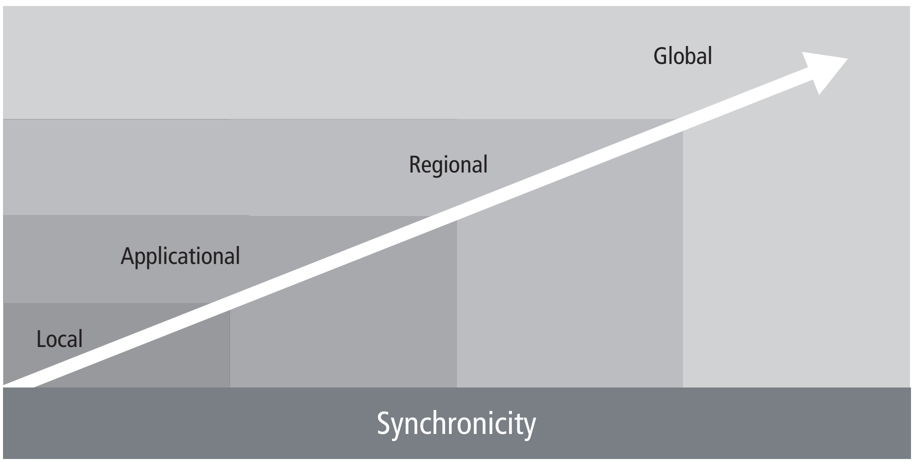

Fig. 1 Synchronicity levels

A Global synchronicity

A common identical system time suffices at global synchronicity level. If, for example, the incoming goods at different container terminals are supervised automatically, then accuracy of the data to one second is adequate. In this manner, it is possible to log how the container moves within the terminals (or how it is relocated) without immense quantities of data resulting.

B Regional synchronicity

Regional synchronicity is necessary for an energy measurement within an extensive network. If the energy data of a 50 Hz network are measured, an accuracy of 1 ms is sufficient in order to be able to pursue and evaluate oscillations through the entire network.

C Applicational synchronicity

In the applicational area of Motion Control, synchronicity of the axes is a must. This applies not only to the chaining of several axes, but also in particular to the axes in the different sections of the plant. If coupled machines are controlled, then the drives must be synchronised with one another to within about 1 millisecond in order to be able to implement highly dynamic movements with precise positioning.

D Local synchronicity

Local synchronicity requires the highest accuracy class, if all devices within a network are to run absolutely synchronously. In the applicational area of PC-controlled laser technology, for example, an accuracy of less than 100 ns is necessary in order to guarantee process stability and to achieve a constant, optimum result. Also, in the acquisition of analog measured values, time differences of 100 ns can significantly disturb the control loop. In this case it is not important that the application is highly synchronous. The emphasis is on detecting these unknown time differences and making them calculable for the application.

Application Note DK9322-0210-0017

External clocks

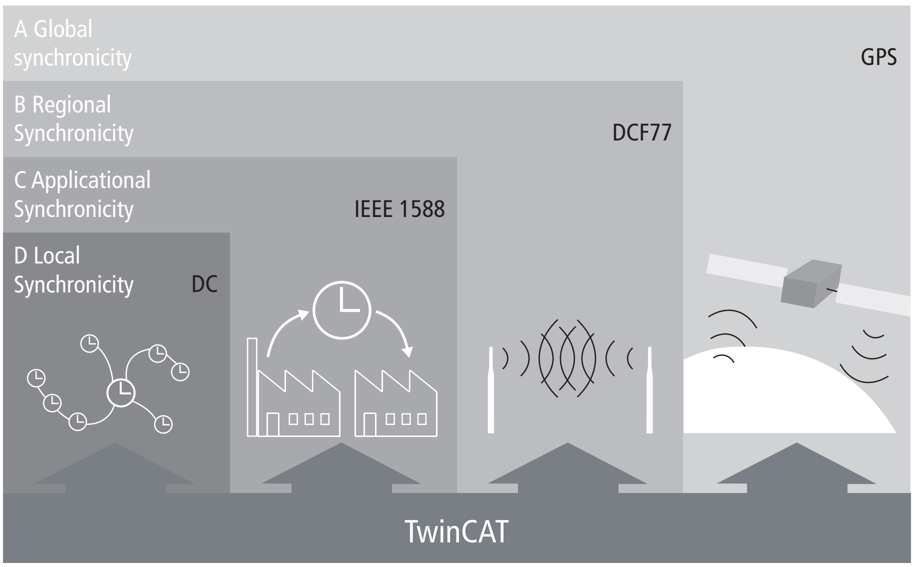

Fig. 2 TwinCAT for all synchronisation levels

TwinCAT is suitable for each of these synchronisation levels. Since not all levels can be resolved using the same technological approach each time, Beckhoff provides different technology for each of these four levels:

A Global

At global level, participants can be synchronised to each other or to external events by using a signal that is available worldwide as an external clock, to which all devices are clocked. A GPS receiver, for example, can function as a clock.

B Regional

Synchronisation at regional level can take place via standardised radio signals, whose reception is ensured in the area to be synchronised. An example: The official time of the Federal Republic of Germany is propagated via the long-wave transmitter DCF77 and can be used within the transmission area (approx. 2000 km around Frankfurt/Main) as an external clock using appropriate receivers.

C Applicational

The **P**recision **T**ime **P**rotocol can be used in order to generate an identical time base within an application, i.e. over several networks. PTP is a protocol that secures the synchronicity of the time settings of several devices in a network and which is defined in IEEE 1588 as the protocol standard for the synchronisation of distributed clocks in networks. As opposed to the NTP (Network Time Protocol), the emphasis in PTP is on higher accuracy. The applicational synchronisation can be implemented using TwinCAT and the **EL6688 IEEE1588 external synchronisation interface**. The EL6688 can work both as an IEEE 1588 master and as an IEEE 1588 slave and supports the versions PTPv1 (IEEE 1588-2002) and PTPv2 (IEEE 1588-2008) on Ethernet basis.

Application Note DK9322-0210-0017

External clocks

In order to achieve synchronisation within an application over several EtherCAT strands with different masters, the **EL6692 EtherCAT bridge terminal** can be used for the synchronisation of the time base. The EL6692 consists of two EtherCAT slaves in one case: the EL6692 on the primary side (terminal bus) and the EL6692-0002 on the secondary side with network cable connection. Both slaves have their own power supplies and are thus independently operational. The primary side is supplied with 5 V DC via the E-bus, the secondary side with 24 V DC via the external connection.

D Local

At local level, using EtherCAT, the distributed clock mode is employed in order to precisely synchronise the different sections and devices of an EtherCAT network to less than 100 ns. The micro-delays in the protocol runtime are calculated and the system times of the individual devices are corrected accordingly. This approach results in the identical system time being present in the entire network. Several EtherCAT components from Beckhoff support the distributed clock mode.

Practical example: retrofit – external synchronisation instead of complete restructuring

In the case of a retrofit, restructuring within the controller of the existing plant can almost always be reckoned with. The complete transition to a powerful controller with the corresponding advantages is decided not only by the costs, but also by the technical feasibility, if further components/plant parts have to be added. In the case that the existing plant cannot be changed, the following example explains how the external synchronisation of EtherCAT segments under TwinCAT can be used in order to match the existing plant and the added components to one another.

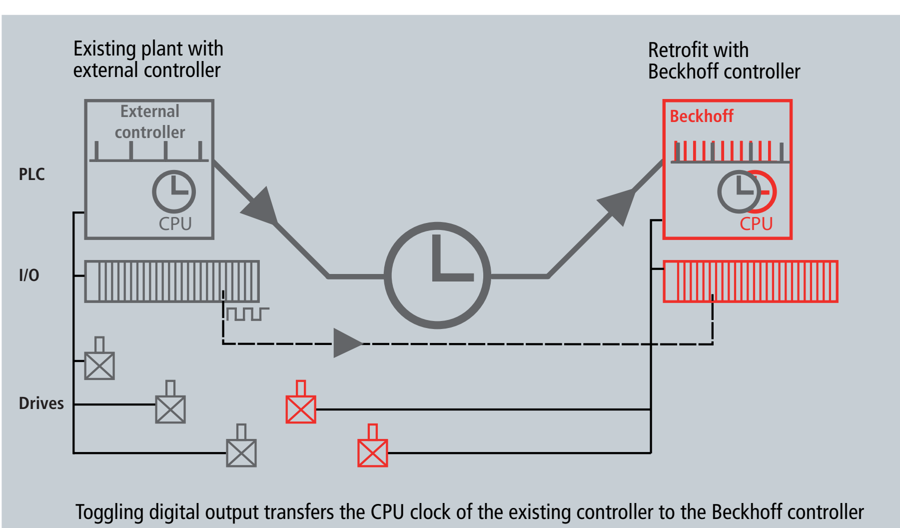

Fig. 3 Retrofit with CPU matching

The existing plant shown on the left (grey – external controller) is subjected to a retrofit; the original controller, including the

Application Note DK9322-0210-0017
External clocks

program, is to be retained/remains unchanged. The newly added components (red – Beckhoff) are drives and their associated controllers. In order to synchronise the Motion Control, which is distributed over two controllers, the CPU clock of the existing controller is made available on a digital output of the existing controller. The signal is received by the supplemented controller via a digital input and used for the synchronisation of its own clock in order to match the CPU clock of the supplemented controller to that of the existing controller.

– PLC and Motion Control on the PC **www.beckhoff.com/TwinCAT**
– Flexible cross-factory synchronisation of EtherCAT networks **www.beckhoff.com/EL6688**
– EtherCAT bridge terminal **www.beckhoff.com/EL6692**