Application Note DK9222-0711-0051

XFC technology microincrements

Keywords
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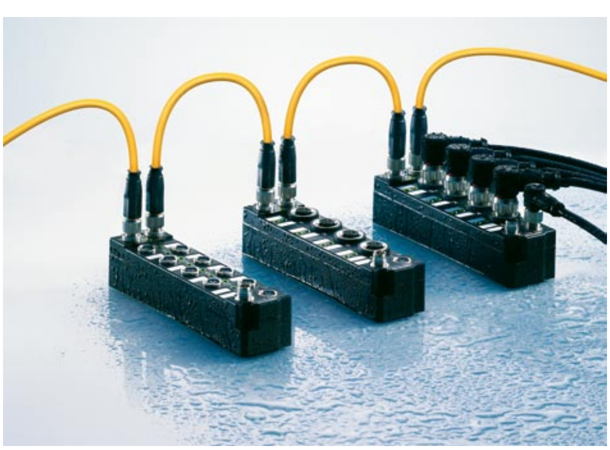
Microincrements | IP67-related solutions

This application example describes how an EP5101 EtherCAT Box can be used in a harsh industrial environment (IP 65/67) to maximize the physical resolution of an incremental encoder. The number of counted encoder segments can be output in more detail with a data width of just 8 bit, i.e. 256 times.

The resilient IP 67 I/O system from Beckhoff

The Beckhoff EtherCAT Box line delivers EtherCAT I/O technology without requiring a control cabinet. All modules from the IP 67 series have an integrated direct EtherCAT interface, so that the protocol's high performance is retained right down to each module. This opens up new options in the IP 67 world: fast process data communication with eXtreme Fast Control (XFC), high precision measurement technology and drive functions integrated into I/O solutions directly in the field. With dimensions of only 126 x 30/60 x 26.5 mm (H x W x D) the modules are exceptionally small and are, therefore, particularly suitable for applications where available space is limited.



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Technical background

The incremental encoder is the main link between the mechanical system and the control system for monitoring mechanical movements. Incremental encoders convert linear or rotary movements into signals that can be analyzed electrically. For rotary movements, a certain number of light/dark segments applied to a pulse disc are scanned with a light beam. A scannable scale arranged in the direction of motion is used for capturing linear movements. The accuracy of the returned position is limited by the encoder resolution. For rotary movements, the resolution corresponds to the quotient of revolution (360°) and number of segments. It indicates the smallest possible measurable difference between two positions. The more segments, the higher the resolution and the more precise the position information. A standard encoder has 1000 lines, resulting in an accuracy of 360° / 1000 = 0.36°. This means a rotary movement can be monitored with a precision of ±0.36°. In many cases, this is adequate for simple positioning tasks, although a finer resolution is required in order to monitor axis synchronism in addition to the position.

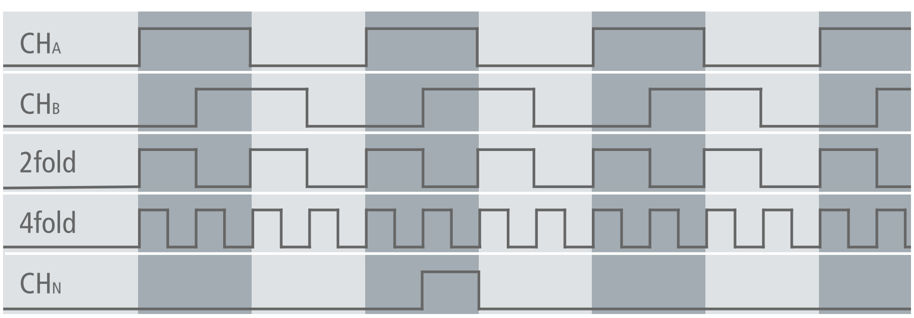

Fig. 1 Encoder signals with different resolutions

Physical improvement of the resolution through maximization of the encoder segments is only feasible to a certain degree, since manufacturing tolerances and operating conditions increase the costs of the encoder. A simple and effective way of maximizing the resolution is to use a second detection point. With two signals that are offset by 90°, three additional edges are available for detection. They can be used to detect the direction of rotation in addition to the position, and an additional reference signal for zeroing is output once per revolution. Analysis of these additional edges can refine the resolution by a factor of 4 (360° / 4 * 1000 = 0.09°), which is why this principle is referred to as quadrature encoder.

Axis synchronism monitoring

Axis synchronism is monitored through cyclic position polling and interpolation of these values within the PLC. The timebase for the interpolation is provided by the strict cycle-linked processing of the instructions in the PLC. With a cycle time of 1 ms (which is common for motion applications), the positions are scanned with a timebase of 1 ms. However, the real encoder scanning intervals are not as rigid as those of the PLC and vary. The reason for the irregularity is inherent to the functional principle variation of the fieldbus transfer times (jitter) and the encoder inaccuracy with ±½ edge. Since the PLC does not take this discontinuity of the polling intervals into account and assumes a constant interval duration, the position representation

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in the process image of the PLC may be unsteady even if the axis is, in fact, synchronous. This only virtual deviation can have three different effects:

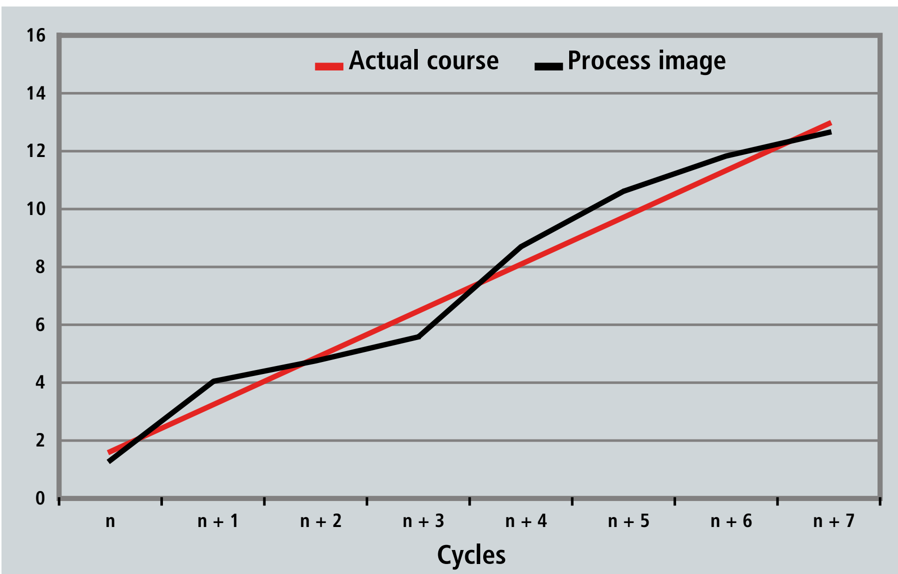

Diagram 1 Asynchronism according to process image

1st case:

Although, in reality, the axis runs absolutely uniformly, the process image shows a non-uniform movement (see Diagram 1)

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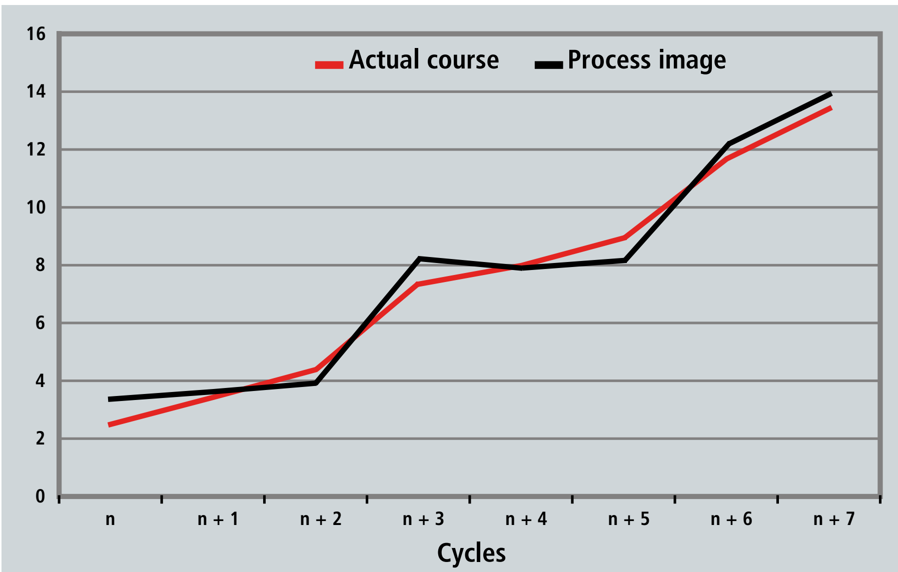

Diagram 2 Amplified asynchronism according to process image

2nd case:

While the axis only runs slightly unevenly, the effect is amplified in the process image (see Diagram 2)

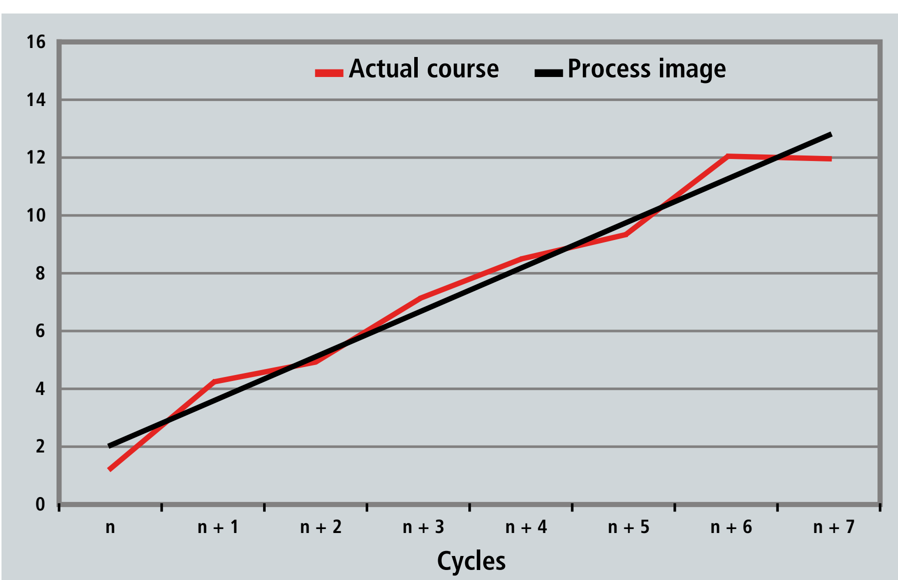

Diagram 3 Equalising asynchronism according to the process image

3rd case:

The axis runs unevenly, the process image equalizes the non-uniform movement (see Diagram 3)

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Synchronization of the strictly cyclical polling through the distributed clock function

High uniformity of the polling intervals can be achieved by using a local clock generator in the EtherCAT slaves, for example, the distributed clock function within EtherCAT (see Fig. 2). This principle is based on measuring the protocol run times within the bus and adjustment of the clock generator clocks in the individual fieldbus slaves. With DC, any run-time difference is known exactly and can be compensated. The polling intervals of the EtherCAT slaves are thus adapted to the strictly cyclic operation mode of the PLC. For distributed clock function, see the distributed clocks system description which is available from the download area under www.beckhoff.com/english/download/ethercat.htm.

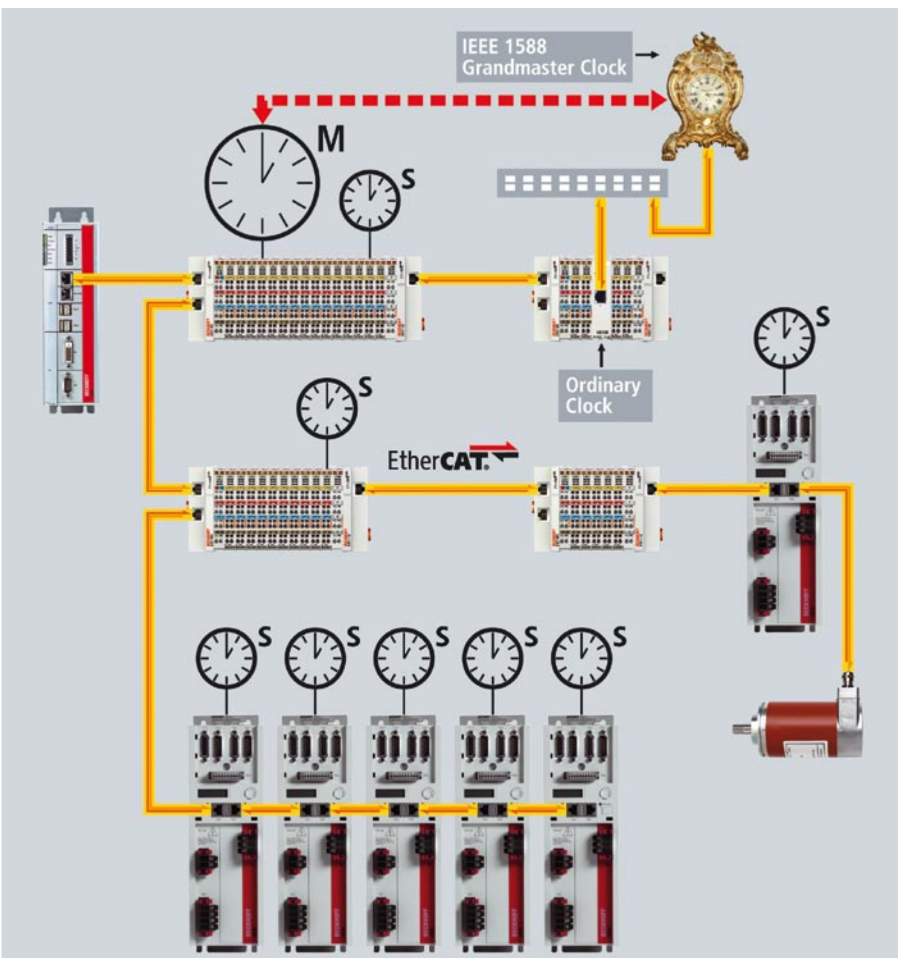

Fig. 2 Local clock generators in the field

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Practical example | Virtual maximization of the physical encoder resolution through microincrements

The semi-edge inaccuracy of the encoder is eliminated by using the microincrement mode of the Beckhoff EP5101 EtherCAT Box with encoder interface. In this mode, the EtherCAT Box automatically interpolates the position scans to be transferred over a width of 8 bits. Therefore, this mode offers a 256 times higher resolution than the encoder is able to provide physically. The microincrement mode is only suitable for motion analyses, because for interpolation within the EtherCAT Box, the position is sampled with a significantly higher resolution than is passed on to the fieldbus in interpolated form. The principle of interpolation in the EtherCAT Box requires a minimum speed, i.e. microincrements cannot be analyzed at (or near) standstill.

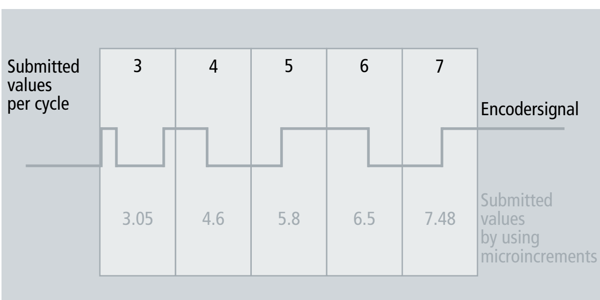

Fig. 3 Different encoder signals resolutions (with and without microincrements)

The EP5101 EtherCAT Box is an interface for the direct connection of incremental encoders with differential inputs (RS485). Due to the optional interpolating microincrement function, the EP5101 can supply even more precise axis positions for dynamic axes. In addition, it supports the synchronous reading of the encoder value together with other input data in the EtherCAT system via high-precision EtherCAT distributed clocks (DC). The encoder is connected via an 8-pin M12 socket (EP5101-0002) or via a 15-pin D-sub socket (EP5101-0011).

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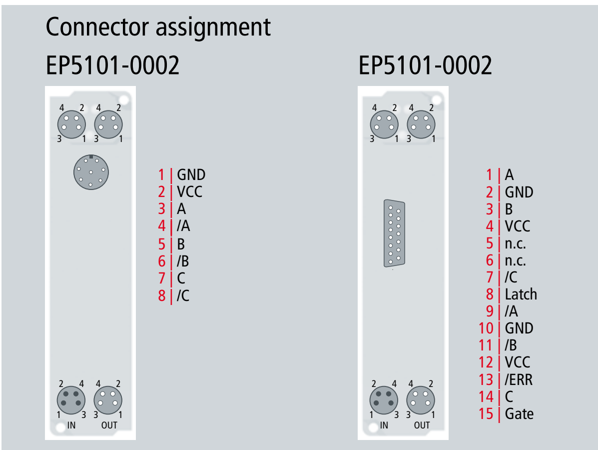

Fig. 4 Connector assignment of the EP5101 EtherCAT Box

– Incremental encoder interface for IP 67 **www.beckhoff.com/EP5101**

– Control architecture for highest performance **www.beckhoff.com/XFC**

– EtherCAT Extends its Reach into the IP 67 World **www.beckhoff.com/EtherCAT-Box**

– EtherCAT **www.beckhoff.com/EtherCAT**