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Application Note

Keywords
Microincrements
Distributed clock
EtherCAT
Encoder

Technical background of incremental feedback systems

Encoders, also known as rotary encoders, are components that play an essential role in monitoring mechanical motion sequences. They are the interface between mechanical and control elements, and are used in automation technology to determine the position, speed, and direction of a linear or rotational movement. There are two different types of position sensors: incremental encoders and absolute encoders.

Incremental encoders are known for their simple and cost-effective design. They report relative position changes, but require homing after they are switched on so that they can determine a known starting point. With each shaft movement, they generate a sequence of pulses known as increments, which are generated by optical, magnetic, or capacitive sensors. These sensors interact with a structure of segments that alternate between those that can be registered and those that cannot. The resolution of an incremental encoder is determined by the number of pulses per revolution: the more pulses per revolution, the finer the position measurement.

An incremental encoder generates two signals, A and B, which emerge when the shaft moves. The square wave signals are phase-shifted by 90 degrees, a process known as quadrature. This phase shift makes it possible to detect the direction of rotation through an evaluation of the phase position of signals A and B in relation to each other. In order to achieve an even higher rotation angle resolution, the falling edge can be evaluated in addition to the rising edge – known as 4-fold evaluation. This technique increases the resolution of an encoder without having to change the physical geometry.

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For rotational movements, the position resolution corresponds to the quotient of one revolution (360 degrees) and the number of encoder increments.
A typical encoder with 12 bits issues 4,096 pulses. With 4-fold evaluation, this results in 16,384 increments, which leads to the following position resolution:

$$\frac{360°}{4{,}096 \times 4} = 0.022°$$

The rotational movement can be resolved to ±0.022°.

Using an encoder shaft with a typical diameter of 10 mm and a travel distance of 10 m results in a linear deviation of approximately ±0.6 mm in the position resolution.

Deviation per revolution: $\frac{0.022°}{360°} \times \pi \times 10\text{ mm} \approx 0.0019\text{ mm}$

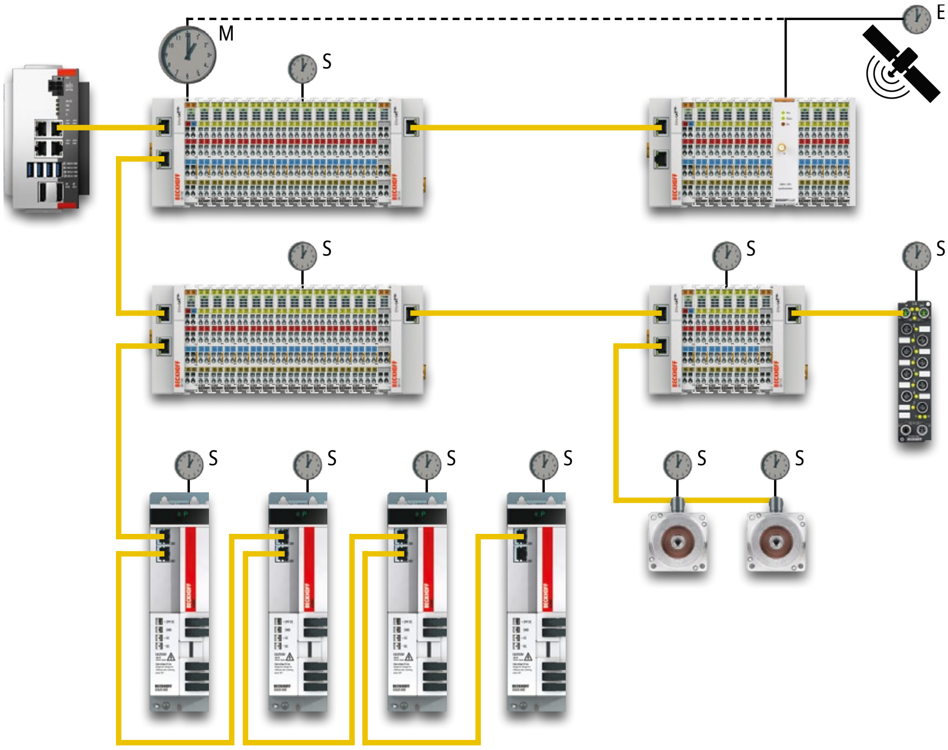
Total deviation: $\frac{10{,}000\text{ mm}}{\pi \times 10\text{ mm}} \times 0.0019\text{ mm} \approx 0.6\text{ mm}$

This resolution is often adequate for simple positioning tasks.

Axis synchronization and challenges when using incremental feedback systems

Synchronizing multiple axes in a machine is a critical aspect of today’s automation technology. It enables precise motion sequences and optimizes the efficiency and productivity of the machine. An incremental feedback system is crucial in this case, as it provides continuous position information that is necessary for accurate control. Axis synchronization increases precision and accuracy, as all movements are coordinated in time and space. In addition, the synchronization of axes enables sophisticated movement patterns that can be easily adapted to different production requirements, increasing the flexibility and adaptability of the machine.

When using an incremental feedback system, it is important to consider a number of aspects: The system must offer a sufficient signal resolution to ensure that positions can be determined with accuracy. A higher resolution enables finer control of the axis movements. The EtherCAT distributed clock functionality helps to standardize the time synchronization of data transmission by providing a common time base for all devices in the network. This allows the data to be retrieved and processed consistently and deterministically at defined points in time, further enhancing system accuracy and efficiency.



Distributed clock functionality for uniform time synchronization

Difficulties can arise if encoders with different resolutions are used. Discrepancies in the accuracy with which positions are determined present one challenge. If axes are controlled with encoders that have different resolutions, this can lead to inaccuracies and inconsistencies in motion control. An encoder with a higher resolution provides finer position data than one with a lower resolution, something which can have a negative impact on the synchronization of the axes and reduce the quality of the end product. It also increases the complexity of data processing, which requires additional computing power and can affect the efficiency of the system.

Not all positioning tasks within a machine require high-resolution encoders. The principle behind microincrements is to provide a cost-effective extension of the incremental encoder functionality in a way that enables finer position measurement.

Maximizing the physical encoder resolution through microincrements

Microincrements make it possible to interpolate additional increments between the steps counted by the encoder. This increases the resolution of the counter value without physically changing the encoder. The principle of microincrements is based on the interpolation of position data with a resolution of 8 bits, which corresponds to 256 additional steps. As a result, the counter value with microincrements comes very close to the real axis position; the queried position corresponds exactly to the physical position at all times. The function is particularly useful at slow speeds, as it helps low-resolution encoders to act like a high-resolution axis encoders.

Distributed clock technology usefully complements the microincrements function by ensuring that the counter reading is determined regularly and consistently, which improves the precision and reliability of the position measurement.

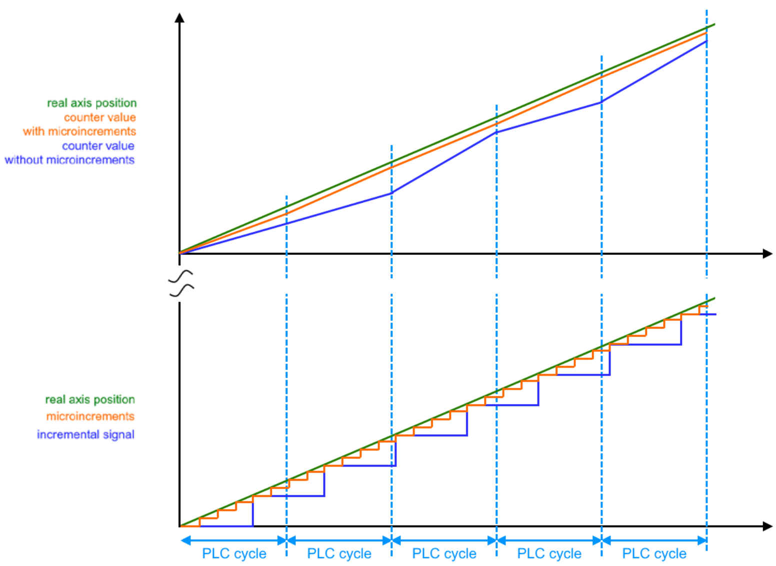
The figure below illustrates the principle of microincrements. Additional steps (orange) between the encoder steps that are actually measured (blue) are interpolated. In the simplified representation, only four microincrements are shown between the encoder steps.

Example:

- Encoder with 1,024 lines
- 4-fold evaluation
- Microincrements enabled, 8 bits

1,024 lines * 4-fold evaluation * 256 micro-increments = 1,048,567 lines

PLC prospective



Summary

The microincrements increase the resolution of an encoder without the need for any physical changes, and ensure precise adaptation of the counter value to the current axis position. This technique is useful in cases where the mechanical design limits the resolution of the encoder and higher accuracy is required.

When multiple axes are synchronized with an incremental feedback system, the function enables uniform and high-resolution position determination, even if encoders with different resolutions are used. The integration of distributed clock technology further improves the synchronization and accuracy of the axes, which is an advantage for sophisticated motion sequences. This is particularly important in automation systems where multiple axes have to be moved simultaneously. Precise control of the movements minimizes unwanted vibrations and mechanical stress, which increases the service life of the machines.

Would you like to find out more?

We are happy to help and look forward to hearing from you:

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