WACHENDORFF
Automation GmbH & Co. KG

Whitepaper
Comparison of optical and magnetic incremental encoders

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Comparison of optical and magnetic incremental encoders

Summary

This whitepaper aims to show the differences, advantages and disadvantages of optical and magnetic incremental encoders.

Therefore only the technologies used by Wachendorff Automation GmbH & Co. KG are discussed.

Incremental encoders in general

Incremental encoders output a certain number of pulses per revolution. The more pulses per revolution, the more accurately an angle and derived quantities can be determined with this encoder. In the simplest case, this signal consists of a so-called track. This is usually referred to as channel A (see Fig. 1).

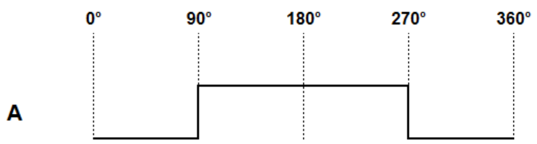

Fig. 1: Channel A incremental encoder (1 ppr)

With the help of this signal, however, under knowledge of the pulses per revolution, only the number of pulses and the speed can be determined. The number of pulses can be used to determine the distance travelled or the change in angle, but not the direction of rotation.

In order to determine the direction of rotation, another signal must be recorded. To do this, a second channel is used, which is shifted by 90° to channel A (s. Fig. 2). The direction of rotation can now also be identified. For example, if channel A is at high level before channel B, the shaft will turn clockwise. If channel B is on high level before channel A, the shaft rotates counter clockwise.

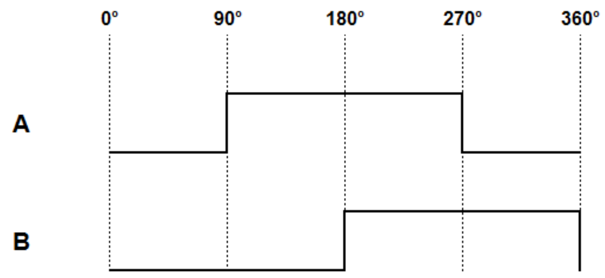

Fig. 2: Channel A and B shifted by 90° (1 ppr)

Incremental encoders often output an additional channel, which can be used to detect how many revolutions have been completed, or to detect a certain point within the revolution. This is channel N (or channel Z / zero signal). If you want to improve the signal quality and noise sensitivity even further, you can also add inverted channels of A, B and N (see Fig. 3). If you measure these signals in differential way, common mode interference is of little or no importance (s. Fig. 4 and Fig. 5).

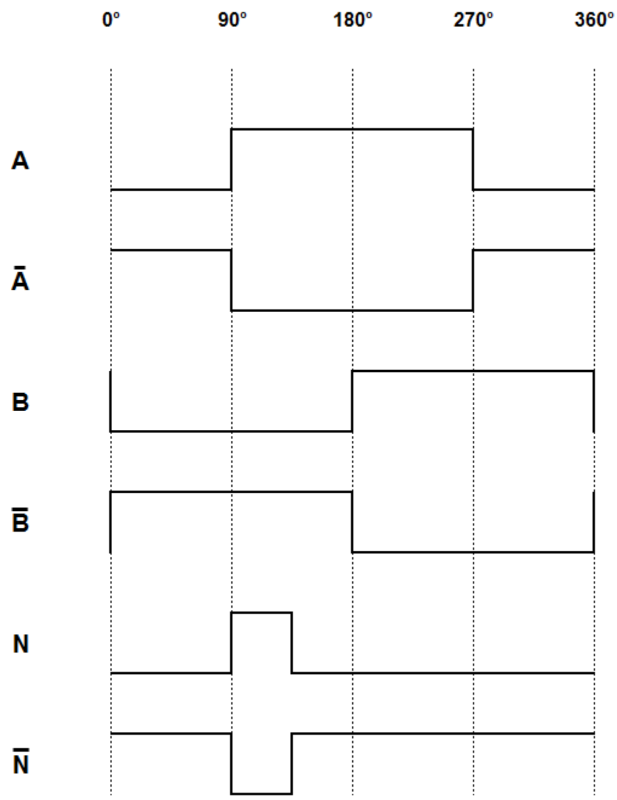

Fig. 3: Channel A,B and N (1 ppr)

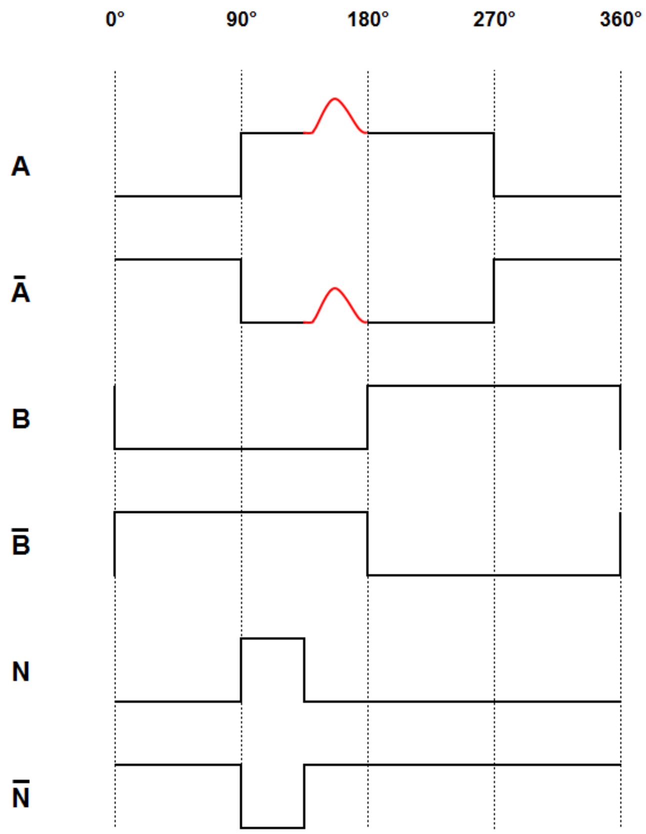

Fig. 4: Interference signal on Channel A and Ā

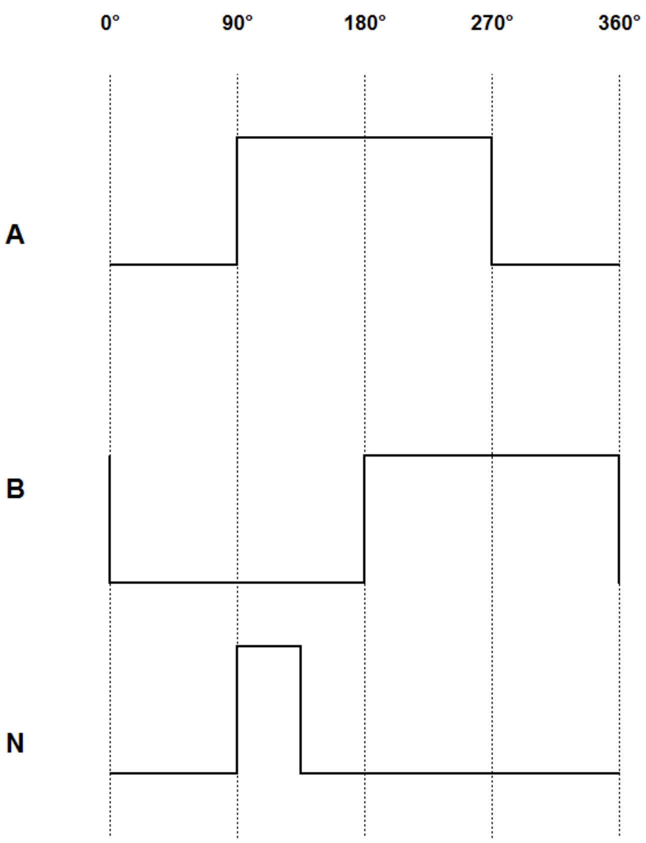

Fig. 5: Result despite malfunction with differential evaluation

Pulses are a signals processed by electronics. The original signal obtained is a sinusoidal or triangular one. Instead of further processing this signal and generating the square wave signal (HTL or TTL) from it, it is also possible to use this sine and cosine signal (Channel A ≙ Sine, since Channel B is offset by 90°, this results in Channel B ≙ cosine). The same information can be obtained from those signals as from pulses (see Fig. 6). Since SinCos encoders work with interpolation, a higher resolution and therefore better accuracy may be achieved than with encoders with square-wave signals.

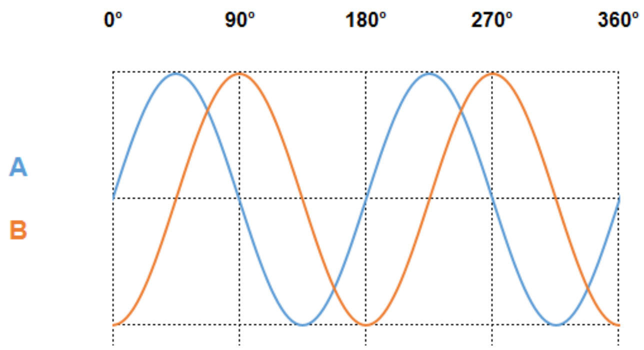

Fig. 6: Sine/cosine channels (2 ppr)

If, for example, you compare a rotary encoder with square-wave signals with a SinCos rotary encoder (both 1024 ppr) and apply a 4-bit interpolation to the SinCos rotary encoder, the interpolated resolution is calculated as follows:

$$1024 \times 2^4 = 16384 \text{ interpol. ppr}$$

This allows the resolution to be increased by a factor of 16 without having to change the hardware. If the encoder is equipped with a variable interpolation rate, several resolutions can be realized with one encoder.

Accuracy of incremental encoders

Two different accuracies can be determined for incremental encoders. They are given in percent and refer to a division length. A division length consists of a pulse and a pause.

The pulse/pause ratio:

The pulse/pause ratio indicates the ratio of pulse to pause duration (seeFig. 7). This means that the ratio of a pulse to a pause is not always exactly the same (50% - 50%). So it is possible that the pulse is longer and the pause is shorter, or the pause is longer and the pulse is shorter.

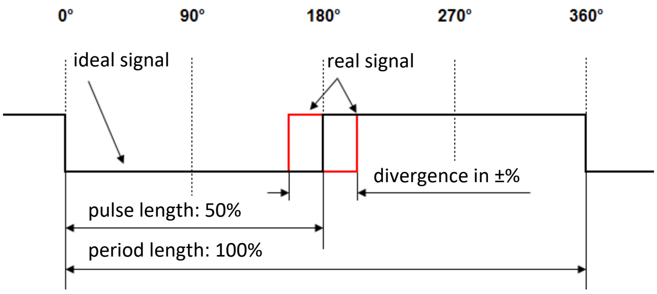

Fig. 7: Pulse/pause ratio

The phase shift:

The phase offset indicates the accuracy of two successive edges (s. Fig. 8). In the ideal case, the distance between two successive flanks is 90° of a division length. In the real case, this distance can be smaller or larger.

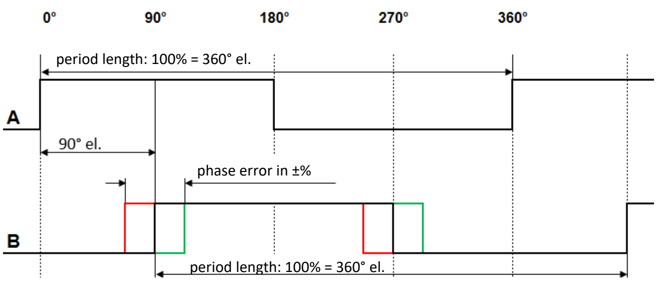

Fig. 8: Phase offset

A phase shift can also be specified for a SinCos encoder. This indicates by how many percent, for example, the maximum of the cosine may be shifted to the maximum of the sine, related to the normal offset of 90° of a period duration (see Fig. 9).

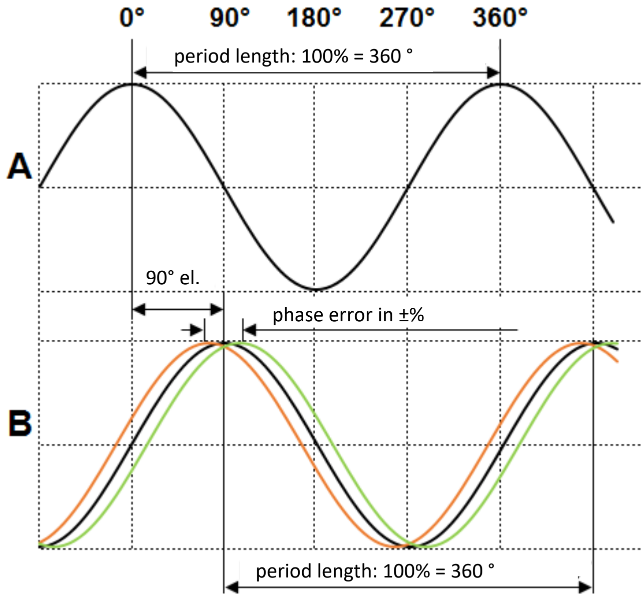

Fig. 9: Phase shift of SinCos encoder

Optical principle

Inside incremental encoders with optical scanning, the light from a high-power LED is aligned in parallel with a biconvex lens and shines through an aperture and a pulse disc (see Fig. 10).

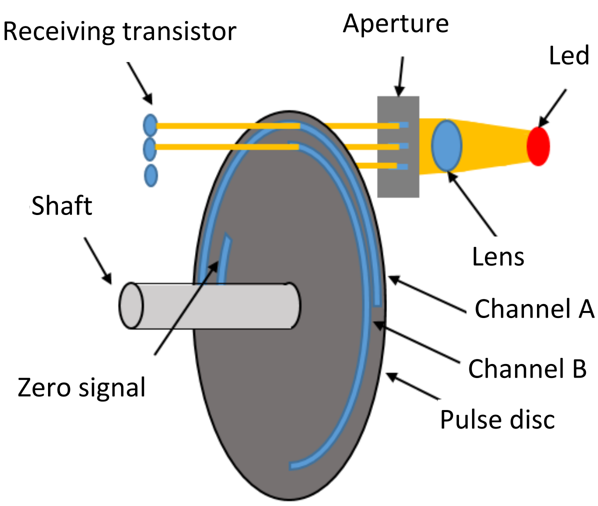

Fig. 10: Simplified structure of an optical rotary encoder

The aperture (see Fig. 11) is integrated in the flange. The pulse disc (see Fig. 12) is mounted on the backlash-free stainless steel shaft.

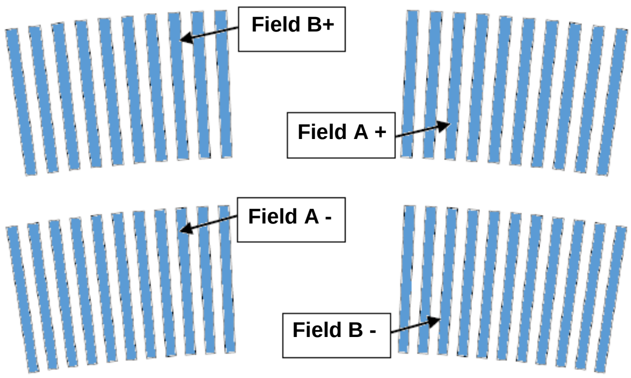

Fig. 11: Bar code of aperture

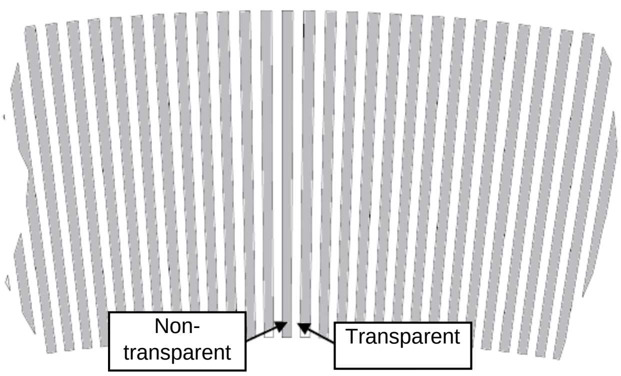

Fig. 12: Bar code of the pulse disc

If the shaft is rotated, finely tuned fields open and close in the combination of aperture disc and pulse disc (see Fig. 13).

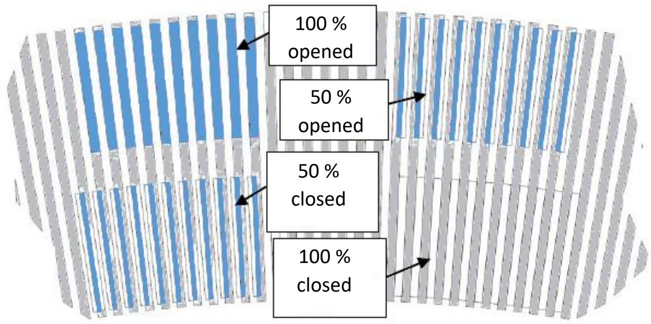

Fig. 13: Overlapping pulse disc and aperture

This allows more or less light to pass through the grids. This difference from light to dark is detected by differentially operating receiving transistors on the opposite mounted circuit board. Due to the special geometric arrangement of the fields on the aperture and the pulse disc, the signals measured in this way are electrically offset by 90°. The downstream electronics process these into high-precision signals and amplify them into industrially usable pulses, such as sine or square waves in HTL or TTL and their inverted signals.

In addition, the zero pulse is applied to the pulse disc and the aperture (see Fig. 10). The zero pulse signal is output once per revolution. Since an incremental encoder only outputs pulses, for some applications a reference run is needed after the machine is switched on. The zero pulse is often used for this reference run. In addition, the zero pulse can be used to validate the counted pulses. If the controller receives the zero pulse after 1030 pulses on a rotary encoder with 1024 pulses, the input card of the controller may have counted interferences on the line as pulses. The controller recognizes the error with the help of the zero pulse and can output an error message.

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Magnetic principle

Incremental encoders, which are based on the magnetic principle, operate with non-contact magnetic scanning. A diametrically magnetized magnet is mounted in the backlash-free stainless steel shaft. If the shaft is rotated, the magnet and the magnetic field also rotate. This change in the magnetic field is detected and processed by a sensor chip on the opposite mounted circuit board (see Fig. 14). This is where the so-called Hall Effect is used.

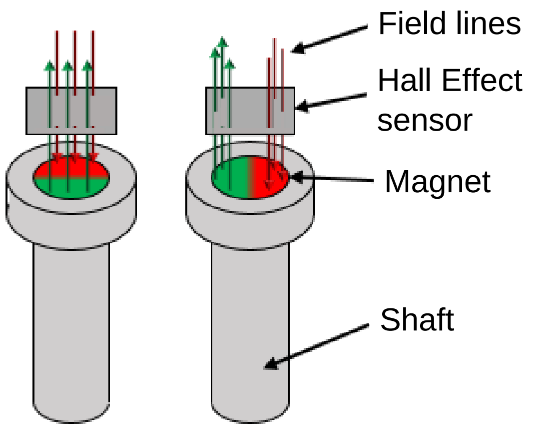

Fig. 14: Schematic structure of a magnetic rotary encoder

As can be seen in the Fig. 15 the magnetic field of the permanent magnet penetrates the sensor chip with its field lines. A voltage is generated in the sensor chip by the magnetic field lines present in the z-axis. The sensor chip is divided into four segments.

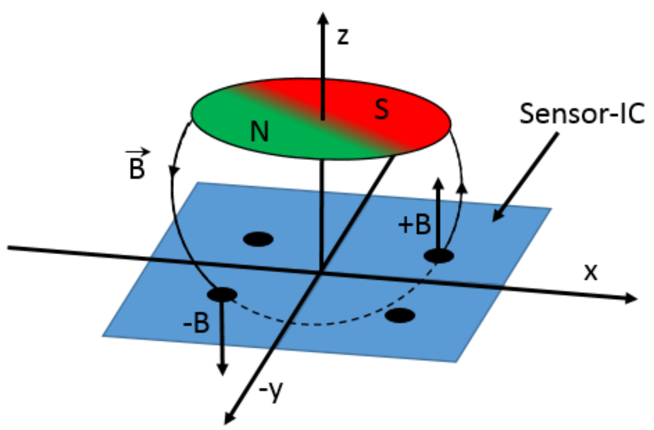

Fig. 15: Sensor IC Hall effect

The voltage generated in the segments is measured differentially. For this the voltage of two different segments is used and with this the two signals offset by 90° are generated.

Strictly speaking, such an encoder is first and foremost a singleturn absolute encoder. The sensor chip resolves the absolute position of the shaft, since the absolute angle can be determined from the now available sine and cosine signal via the trigonometric relationships. An interpolator then generates the channels (A, B and N) from the absolute position and outputs them. Simplified, this could be done as follows. Each time the position value changes, an edge of channel A or B changes depending on the direction of rotation and the zero pulse is output at position value 1 (see Fig. 16).

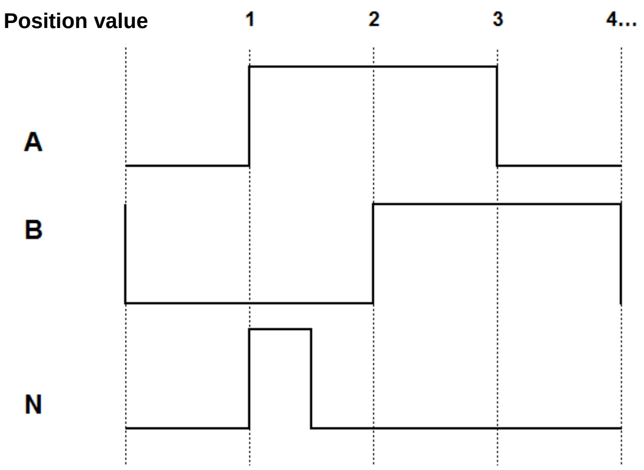

Fig. 16: Example absolute value -> incremental pulses

Here, too, high-precision signals are processed and amplified from the signals obtained by the downstream electronics in order to output them as industrially usable square-wave pulses in HTL or TTL and their inverted signals.

Our encoders are finely tuned measuring systems with precise mechanics, efficient sensor technology and powerful electronics.

Advantages and disadvantages:

Magnetic principle:

– Influence of very strong magnetic fields possible
– Accuracy not yet as high as with optical systems
– limited resolution

+ Very insensitive to environmental influences
+ more convenient

Optical principle:

– sensitive to environmental influences

+ High resolution and accuracy possible
+ Very insensitive to magnetic influences

(Number of points has no weighting)

Conclusion:

The perfect principle does not yet exist. As you can see from the advantages and disadvantages, it depends on the application in each individual case which principle will produce the best result. Both principles are getting closer and closer to each other. The magnetic systems become more accurate through continuously improved sensor technology and thus come more close to the accuracy of optical systems. Again, the robustness of the optical systems is getting better and is becoming less sensitive to shock and vibration. We are happy to help you with your decision.

Wachendorff introduces himself:

Wachendorff Automation GmbH & Co KG develops and manufactures rotary encoders, motor feedback and complete measuring systems for use in a wide variety of series applications in machine and plant construction. An extensive standard range with numerous options as well as efficient development of customer-specific solutions is a matter of course for us as an owner-managed medium-sized company based at beautiful Rheingau, west of Wiesbaden. Competent, personal advice from person to person and sustainable cooperation with our business partners are the cornerstones of our continuous growth. We are certified according to DIN ISO 9001 and DIN ISO 14001.

Author:
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Product manager

Sources:

Wachendorff Automation - *General technical data incremental encoders*
Springer Trade Media Wiesbaden 2016 S. Basler - *Encoders and Motor Feedback Systems*

www.wachendorff-automation.com

The Wachendorff Group

- Delighted customers
- Corporate responsibility
- Attractive for good employees
- Outstanding quality
- Technology leader
- Environmental protection
- Profitable growth

We are a medium-sized owner-managed corporate group based in the beautiful Rheingau district, situated to the west of Wiesbaden.

Competent, personal, face-to-face advice and long-term collaboration with our business partners are the cornerstones of our continual growth. We are certified according to DIN ISO 9001 and DIN ISO 14001.

Wachendorff Automation GmbH & Co. KG
The development and manufacturing of rotary encoders, engine feedback devices and complete measuring systems for use in a wide range of serial production applications in mechanical and plant engineering. An extensive standard range featuring numerous options and efficient development of customised solutions.

Wachendorff Prozesstechnik GmbH & Co. KG
A reliable supplier since 1978 of robust, high quality industrial devices for visualizing, communicating and processing data in the areas of mechanical, plant and building automation.

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