

Description

Device for identifying the direction of rotation and testing plausibility in absolute angular position encoders, especially with serial transmission of detected
5 actual position values

In absolute angular position encoders, actual position values can be transmitted, preferably serially, for example to a controller for further processing, in binary form at predefined time intervals. Since the
10 operation of serial data transmission of all the bits of an actual value of this type that is encoded in binary form takes up a specific time duration, however, in exceptional cases, the real actual value can vary sharply during said operation.

15 A first case of this type is presented when the shaft of the absolute angular position encoder temporarily rotates at a high rotational speed, for example because of an excessive speed that is intrinsically inadmissible. In this case, the factual position of the shaft
20 may change by many distance units between the beginning and end of the serial, bitwise transmission of an actual position value that was detected previously. The subsequent, serially transmitted actual position value then has an absolute magnitude which has changed in an unexpectedly abrupt manner. A further case of this type is
25 presented when errors occur during the serial data transmission. In this case, high-value bits in the encoding of the actual position value can be falsified in the serial data stream, for example caused by electromagnetic
30 irradiation. In this case, too, actual position values may have an absolute magnitude which, induced by the error, changes in an abrupt manner. If such abrupt changes in an actual angular position value are fed to a controller, for example, then both the identification of
35 the direction of rotation of the shaft of the angular position encoder, and the testing of the plausibility of the incoming actual position values, are made more

difficult there.

In normal operation, the direction of rotation of the shaft of the angular position encoder can be ascertained in a simple way, in that the

difference between successive actual values is formed. If the sign of "current actual position value - previous actual position value" is positive, then the rotation is "forward", for example; if a negative sign occurs, then the rotation is "backward". However, a precondition for the functional capability of this method is that the two actual values in the above difference always lie so close to each other that such a pair in each case lies either "before" or "after" the so-called zero point of the shaft of the angular position encoder. Hence, the absolute magnitudes of the two actual values must generally not deviate sharply from each other.

However, this in turn means that the rotational speed of the shaft of the angular position encoder, and the rapidness of the serial data transmission, must always be matched to each other in such a way that one of the two values of the pair is not acquired "before" and the other value "after" passing over the zero point. In such a case, an erroneous direction of rotation would be determined. If the old actual value, lying "before" the zero point, is 3550, for instance (corresponding for example to an actual position value of 355,0 degrees), and the new actual value, lying "after" the zero point, is 50 (corresponding for example to an actual position value of 50.0 degrees), then the difference "current actual position value - previous actual position value", that is to say 50 - 3550 in the example, results in a negative sign, although the shaft of the angular position encoder has been rotated forward over the zero point. On the other hand, actual position values which have been severely falsified in terms of magnitude as a result of electromagnetic irradiation must also not be used for the difference formation. There is the risk in this case, too, that an erroneous direction of rotation will be determined.

Actual position values which have changed sharply in an unexpected or error-induced manner also constitute a problem if this are checked for so-called plausibility, for example in a controller. To this end

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it is generally assumed that the change in the incoming

actual position values takes place in an approximately quasi-continuous manner. It is then possible to check whether their absolute magnitude exceeds a predefined, maximum admissible rate of change. By this means, actual position values that are unusable, for example falsified because of errors during the serial data transmission, can be filtered out. On the other hand, such large jumps in the actual value can also occur unexpectedly when the matching between the speed of the serial data transmission and the rotational speed of the shaft of the angular position encoder is disturbed, for example as a result of a temporary, intrinsically inadmissible, excessive speed of rotation. Such large, faulty or unexpected jumps in the actual value can then be confused with admissible jumps in the actual value, which always occur during the acquisition of the angular position.

During the acquisition of the position of the shaft of an angular position encoder, the actual value specifically changes from the maximum value to the starting value or zero value, or vice versa, at the moment of travelling over the so-called zero point. Given an encoder with, for example, a so-called 0.1° resolution of a complete revolution of the shaft being monitored, the binary coding of the actual value changes from a maximum value of 3599 (corresponding, for example, to an actual position value of 359.9 degrees) to 0 (corresponding, for example, to an actual position value of 0 degrees) when travelling over the zero point. Such jumps in the absolute magnitude of the actual position value are admissible only at the moment of passing over the zero point and must be identified as such. If, however, as described above, sporadically unexpected or error-induced large jumps in absolute magnitude occur, both the identification of the direction of rotation of the shaft and the testing of the plausibility of incoming actual position values are hampered by this, for example in a controller carrying out the evaluation.

The invention is based on the object of specifying a circuit using which, in the case of an absolute

angular position encoder, in spite of any possible occurrence of large changes in absolute magnitude in the detected actual angular position values, the direction of rotation of the shaft

of the angular position encoder can be ascertained correctly, and the plausibility of the actual position values can be checked.

The object is achieved with the device specified
5 in claim 1. Advantageous further refinements of the same are specified in the subclaims.

The invention will be explained further with the aid of the appended figure, which shows a cross section through the shaft of an angular position encoder.

10 Firstly, a first value V is ascertained by the circuit according to the invention, for example during the commissioning of the angular position encoder, and stored in a store. The said value corresponds to the number of angular units which are covered during two
15 successive transmissions of actual position values over the respective serial data transmission link when the maximum admissible rotational speed of the shaft of the angular position encoder is present. This value is thus a measure of the capacity of the serial data transmission
20 device respectively used in relation to the largest possible rate of change of the actual position values to be acquired and to be transmitted, and corresponds to the largest possible angular distance between two success-
25 ively acquired and transmitted actual position values. Since in the normal case the rotational speed of the shaft will be lower than the maximum value, actual position values normally lie closer to one another. Consequently, the value represents firstly the current acquisition speed of successive actual position values,
30 and also secondly the maximum value possible in this case of the step height in the absolute magnitude of the actual values.

Furthermore, a second value D is determined by the circuit according to the invention and, if appropri-
35 ate together with the first, corresponds to the difference between the maximum travel MAX of the angular position encoder and the first value V, that is to say $D = (MAX - V$

). Value V likewise stored in the store. This value thus corresponds to the position value of the shaft of the angular position encoder, whose acquisition and serial transmission, for example to a controller, given the presence of the maximum rotational speed of the shaft, would occupy precisely so much time that the subsequently detected actual position value would coincide with the so-called rotary encoder final value MAX. This rotary encoder final value is the actual position value to which, also depending on the respective binary encoding, the maximum occurring absolute magnitude is assigned. As a rule, it lies before the so-called zero point of the encoder only by an angular value that corresponds to the resolution of the angular position encoder.

In the case of the example drawn in the figure, let it be assumed, in the same way as already assumed above, that the angular position encoder is able to acquire position changes of its shaft W with a resolution of 0.1° . It is then advantageous if the smallest absolute magnitude $A = 1$ is assigned to this smallest measurable angular range. Given a resolution of 0.1° , the maximum actual position value that can be acquired has the magnitude of 359.9 degrees. This final value, lying directly before the zero point NP of the shaft W, of the angular position encoder is then assigned the maximum absolute magnitude of $MAX = 3599$. Let it further be assumed that the shaft W of the angular position encoder, given the presence of the maximum admissible rotational speed, rotates further by an angular range of 10° between the acquisition and transmission of two successive actual position values. In this case, the magnitude 100 results for the first value V ($V = 10^\circ$ divided by 0.1°), and $D = MAX$ minus $V = 3599 - 100 = 3499$ results for the second value. In the figure, the actual position values L1 and L2 are illustrated to the right and left of the zero point NP of the shaft W. The actual position value $L1 = 3499$ in this case lies by the magnitude of the first value V (100) plus the resolution A (1), that is to say

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precisely by the magnitude of the second value D, "before" the zero point NP. The second actual position value $L_2 = 100$ lies "after" the zero point by the magnitude of the first value V (100).

The circuit according to the invention can now ascertain, via a processing unit and with the aid of the two values V and D, whether a currently detected actual position value and the associated actual position value which was acquired in the immediately preceding cycle, has been transmitted and is thus already located in the store, is located immediately to the left or right of the zero point NP and whether thus the case has occurred in which the actual position values to be brought into conjunction with each other in order to identify the direction of rotation are exceptionally not both located together on one side of the zero point. To this end, the actual values are compared with the respective magnitudes of the two stored values V and D with the aid of comparison means of the circuit according to the invention.

The invention will be explained with the aid of the figure, using the example of three pairs of associated actual position values X11, X12 and X21, X22 and X31, X33, the values Xx2 representing the respectively current, newly acquired and transmitted actual position value, and the values Xx1 representing the respectively preceding actual position value acquired in the previous cycle, x being 1, 2, 3.

If, in a first case, this comparison yields the result that a current actual position value X12 lies in the range between the zero point NP and the actual position value L2 corresponding to the magnitude of the first stored value V, that is to say to the right of the zero point in the figure, and in addition the previous actual position value X11 lies in the range between the actual position value L1 corresponding to the magnitude of the second stored value D and the rotary encoder final value MAX, that is to say to the left of the zero point in the figure, that is to say if the following conditions are satisfied

$$NP < X12 < V \quad (\text{Eq. 1})$$

$$D < X11 < MAX \quad (\text{Eq. 2}),$$

then the circuit according to the invention ascertains a positive direction of rotation.

If, in a second case, this comparison yields the result that a current actual position value X22 lies in the range between the actual position value L1 corresponding to the magnitude of the second stored value D and the rotary encoder final value MAX, that is to say to the left of the zero point in the figure, and in addition the previous actual position value X21 lies in the range between the zero point NP and the actual position value L2 corresponding to the magnitude of the first stored value V, that is to say to the right of the zero point in the figure, that is to say if the following conditions are satisfied

$$15 \quad D < X22 < MAX \quad (\text{Eq. 3})$$

$$NP < X21 < V \quad (\text{Eq. 4}),$$

then the circuit according to the invention ascertains a negative direction of rotation.

If one of the two conditions in one of the above pairs of equations Eq.1, Eq.2, or Eq.3, Eq.4 is satisfied, then the zero point NP of the shaft W of the angular position encoder has been passed over, and the two values to be processed in relation to each other in order to acquire the current direction of rotation do not lie together as a pair on one side of the zero point NP.

If, in a third case, this comparison yields the result that none of the conditions in the above equations Eq.1 to Eq.4 is satisfied, then the two actual position values do not lie close to or about the zero point NP. One pair of such actual position values X32, X31 is drawn in the figure. The difference between the current actual position value X32 and the previous actual position value X31 is then formed as previously. If the sign of this difference is positive, then the direction of rotation is positive, otherwise is negative. In the example in the figure, the direction of rotation is positive.

The invention has the advantage that, in spite of the possible occurrence of unexpected or error-induced large changes in absolute magnitude in the detected actual angular position values, the direction of rotation of the shaft of the angular position encoder can be ascertained correctly in each case. The invention has the additional advantage that it can be expanded in a simple way by an additional plausibility test of acquired actual position values.

To this end, the magnitude of the difference "current actual position value - previous actual position value" is formed. If this magnitude is greater than the first stored value V, then one of the two actual values is erroneous, since the values on the circumference of the shaft then, so to speak, lie too far apart from each other. A magnitude of this amount can only occur if either the factual rotational speed is higher than the maximum admissible speed, or an actual position value has been falsified, for example as a result of electromagnetic irradiation during the serial data transmission. If such an erroneous pair of position values occurs, these cannot be processed further, but must be discarded. This supplement to the invention has the advantage that the actual position values transmitted can be checked for plausibility even if no data-securing methods, for example by means of adding redundant items of information such as parity or check sum bits, are used during the serial data transmission.

Patent claims

1. A device for identifying the direction of rotation of an absolute angular position encoder, to which device the actual position values are fed via a preferably serial data transmission link, having
- 5 a) a store in which the following are stored
- a1) a first value (V) which corresponds to the angular units covered during two actual position values successively transmitted via the data transmission link at the maximum rotational speed of the encoder shaft (W), and
- 10 a2) a second value (D), which corresponds to the difference between the maximum travel of the angular position encoder (MAX) and the first value (V) ($D = MAX - V$), and having
- 15 b) a processing unit which determines the direction of rotation of the shaft (W) depending on whether two actual position values (X11, X12; X21, X22; X31, X32) lie in the range
- 20 between the zero point (NP) of the angular position encoder and an actual position value (L2) corresponding to the magnitude of the first stored value (V), or in the range between an actual position value (L1) corresponding to the magnitude of the second
- 25 stored value (D) and the maximum travel (MAX), or outside these ranges.
2. The device as claimed in claim 1, the processing unit
- a) detecting a positive direction of rotation if



- a1) a current actual position value (X12) lies in the range between the zero point (NP) and an actual position value (L2) corresponding to the magnitude of the first value (V), and
- 5 a2) the previous actual position value (X11) lies in the range between an actual position value (L1) corresponding to the magnitude of the second stored value (D) and the maximum travel of the angular position encoder (MAX), and
- 10 b) detecting a negative direction of rotation if
- b1) a current actual position value (X22) lies in the range between an actual position value (L1) corresponding to the magnitude of the second stored value (D) and the maximum travel of the angular position encoder (MAX), and
- 15 b2) the previous actual position value (X21) lies in the range between the zero point (NP) and an actual position value (L2) corresponding to the magnitude of the first stored value (V).
- 20 3. The device as claimed in claim 1 or 2, the processing unit forming the direction of rotation by forming a difference between the two successive actual position values (X11, X12; X21, X22; X31, X32) if none or a maximum of one of the two actual position values (X32,
- 25 X31) lies either in the range between an actual position value (L1) corresponding to the magnitude of the second stored value (D) and the maximum travel of the angular position encoder (MAX) or in the range between the zero point (NP) and an actual position value (L2) corresponding to the magnitude of the first stored value (V).
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4. The device as claimed in one of the preceding claims, the processing unit forming the absolute magnitude of a difference between the two actual position values (X11, X12; X21, X22; X31, X32) and discarding the
- 5 actual position values as lacking plausibility if the value of the absolute magnitude is greater than the first value (V).

