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CONDITION OF MEASUREMENT CHAIN WITH LINEAR ENCODER

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Abstract: The paper deals with experimental identification of condition of measurement chain with linear encoder. Verification had been executed through the using set of length gauges. The manufacturer of the sensor notes a lot of parameters but there is no mention about sensor uncertainty or maximum error. Uncertainty of measurement is inseparable part of measurement result.

1 Introduction

The encoder can be either incremental or absolute. Motion can be determined by change in position over time. Linear encoder technologies include optical, magnetic, inductive, capacitive and eddy current. Optical technologies include shadow, self imaging and interferometric. Linear encoders are used in metrology instruments, motion systems and high precision machining tools ranging from digital calipers and coordinate measuring machines to stages, CNC Mills, manufacturing gantry tables and semiconductor steppers. Optical encoders are the most accurate of the standard styles of encoders, and the most commonly used in industrial automation applications. Light sources used include infrared LEDs, visible LEDs, miniature light-bulbs and laser diodes.

Incremental position encoder (fig. 1) is also called as pulsed encoder or incremental relative encoder IRC [1], [2].

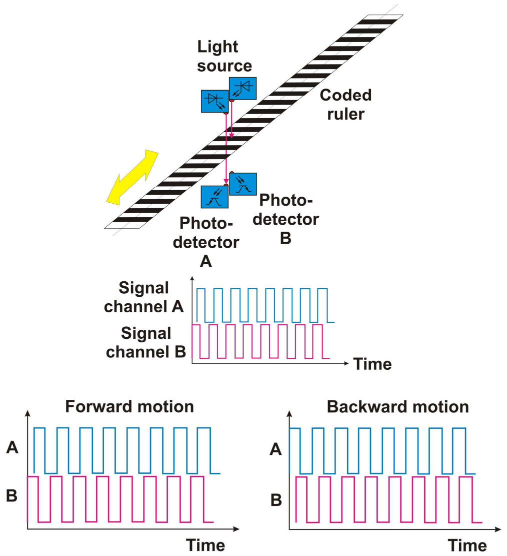

Figure 1 Incremental optical encoder principle and recognition of motion direction of optical incremental encoder

Principle of incremental encoder lies on fact that movement of the measured object causes the change of reference coded ruler position. Reference coded ruler consist of dark segments alternates transparent segments.

Light from optocoupler is interrupted with dark segments. This arrangement produces square wave (fig. 1).

Direction of movement is recognized via using of another optocoupler shifted 90° out of phase from each other with the direction of movement. These two channels of square waves A and B can be completed with channel C called as reference which gives information about reference mark as end point, mid point etc. (fig. 1).

The aim of this paper is to identify condition of the measurement chain with incremental optical linear encoder. The main advantage of using the encoder for distance measurement is relativelly resistant to noise. The tested encoder is usable in any position.

Signal from the encoder is captured with DAQ board (data acquisition board) MF624 by Humusoft company. DAQ board is in PCI slot of PC. Data capturing is made in Matlab/Simulink environment. Using of the DAQ board is easy and it is also used for practical exercises of students. Overal measurement chain is shown on figure 2.

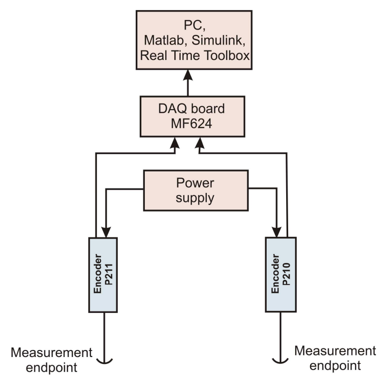

Figure 2 Measurement chain with two tested optical incremental encoders

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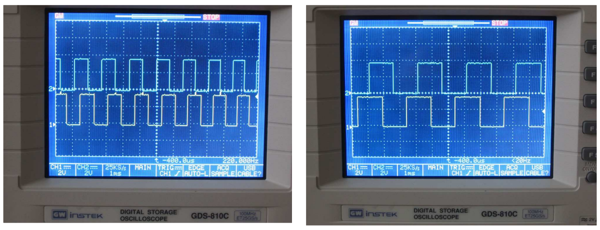
Encoder is made in steel case with same gripping as dial indicator frequently used in dimensional metrology. It means that standard dial indicators stands can be used as holder.

2 TTL logic signal from encoder

Optical system in encoder generates the square signal with TTL levels. Logical zero is represented through the voltage 0V and logical one is represented through the voltage 5V. Squares on encoder output is also called as increments.

The DAQ board is also able to measure TTL logic levels. The using of the TTL logic also allow to use the any TTL microcontroller which is cheaper solution for data acquisition.

Optical system uses the infrared focused light and linear rule. Infrared light is used because of day light elimination. One period of signal is equal to step 5μm (fig. 1). This square signal is connected to encoder input on MF624 DAQ board. Encoder includes two pairs of optical system (transmitter-receiver or also called as optocoupler). Second optocoupler is shifted because of ability to recognize the direction of moving of measure rod with sensing endpoint of encoder. It is labelled as channel A and channel B. Function of both channels are verified with oscilloscope (fig. 3).



a) b)
Figure 3 Time dependence of output sensor signals
a) Measure rod is shifting inside, b) Measure rod is shifting outside

3 Data acquisition

Data capture on DAQ board MF 624 is processed in Matlab/Simulink (fig. 4). Block "*Adapter*" represents used DAQ board MF624 and it enables tu configure selected DAQ device. Also it is possible to use more adapters continuously. Blocks "*RTIn*" allows to capture data directly to matlab environment. It is necessary to configure blocks "*RTIn*", set up the channel number and sample time. The used computer allows maximum samplet time 0.001s but MF624 allows the 100kHz sampling frequency. Real sample time strongly depends on used computer and operating system. Blocks "Gain" are used for recalculation of number of square pulses to length in milimeters. Blocks "Display" are used for displaying of measured value. Also it is necessary to configure these blocks (sample time and number format). Structure in Simulink also includes the writing of measured data to file.

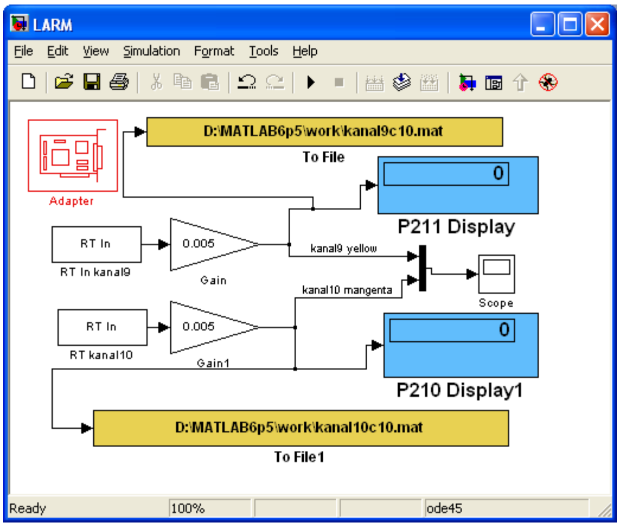


Figure 4 Data processing in Matlab/Simulink

4 Calibration of tested encoders

Structure of calibration procedure of encoders is shown on figure 5. Both tested linear encoders are holded in dial indicator stands. Calibration has been executed via using of set of length gauges (fig.5).

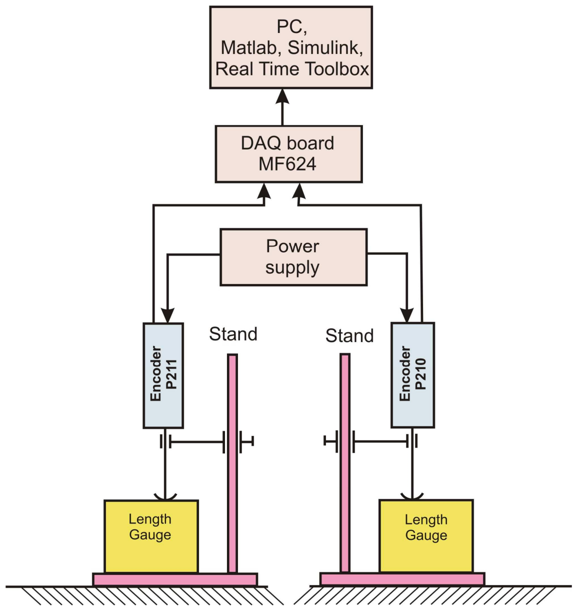


Figure 5 Calibration process structure

Both encoders have measurement range 30mm. Calibration step has been selected 0.1mm. It means that full encoder range is divided into 300 checked values and every value is measured 10 times.

Temperature in laboratory has been maintained on value 20°C±1°C.

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Figure 6 Set of length gauge blocks and building of length etalons

Producer of the length gauges (fig. 6) provides a table with systematic errors for every length gauges in set. Every calibrated dimension requires the specific etalon with nominal length L_{BM} - block of length gauges. The overall systematic error for every etalon L_{BM} - block (every dimension) can be obtained as sum of systematic error for every used length gauge used for building of etalon – blocks L_{BM} (fig. 5).

$$\delta_{BM} = \sum_{Mi=1}^{Mn} \delta_{Mi} \qquad (1)$$

Where δ_{BM} is overall systematic error of etalon L_{BM} (block of gauges); δ_{Mi} is systematic error of used length gauges; M_n is number of used length gauges.

Every checked value L_{BM} has different overall systematic error of etalon, because different pieces of length gauges have been used. Every piece of length gauge has different systematic error. Every measured value L_{BM} has been corrected with relevant summary of length gauges systematic error of etalon via using of the equation:

$$X_{KOR} = X_{NAM} - \delta_{BM} \qquad (2)$$

Where X_{NAM} is measured value of etalon; X_{KOR} is corrected measured value of etalon. Measured value is obtained from display block in Matlab/Simulink.

Every value of etalon L_{BM} has been measured ten times at the same conditions (fig. 7). The estimation of mean value is calculated as arithmetic average:

$$\overline{X}_{KOR} = \frac{1}{n}\sum_{i}^{n} X_{NAMi} \qquad (3)$$

Where X_{NAMi} is measured value of etalon from display block in Matlab/Simulink; n is number of measured values.

Figure 7 Calibration process

Comparing of corrected measured value (from display block in Matlab/Simulink) and nominal values of etalon L_{BM} is error of measurement chain with encoder:

$$\delta_{ENCODER} = \overline{X}_{KOR} - L_{BM} \qquad (4)$$

Values of errors from encoder 1 and encoder 2 are shown on figure 8 and figure 9.

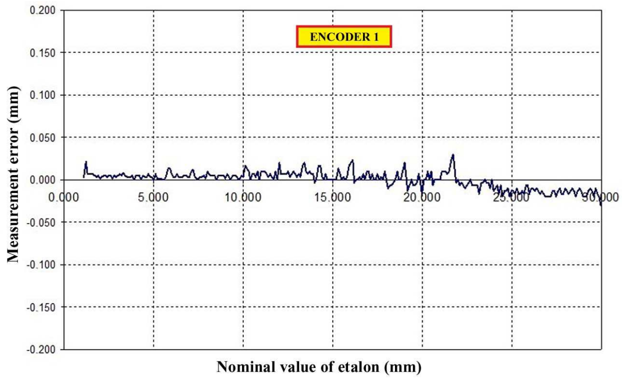

Figure 8 Measured errors on encoder 1

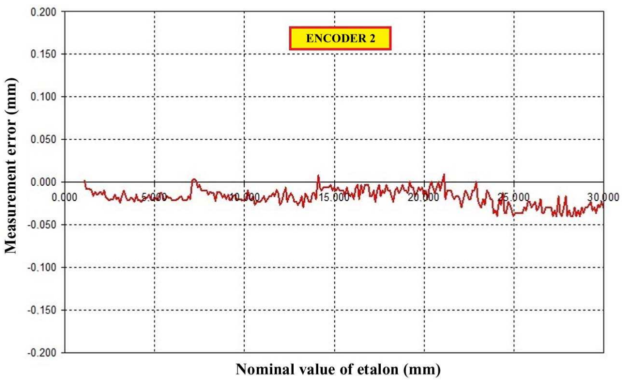

Figure 9 Measured errors on encoder 2

Uncertainty of measurement on encoders can be obtained as quadratic sum of all uncertainties of all parts on measurement chain with encoders.

Uncertainty of length gages are too low in compare with encoders, so they can be neglected. Counters on DAQ board MF624 has high resolution (the resolution is 32 bit, 20ns), so also uncertainty of DAQ board can be neglected.

Maximum errors obtained from calibration can be used as uncertainty of type B. Uncertainty of type A is defined as standard deviation from minimum of ten measurement at the same condition. This uncertainties can be summed into combined uncertainty:

$$u_C = \sqrt{u_a^2 + u_b^2} \qquad (5)$$

On the base of the mentioned, it is possible to calculate maximum value of uncertainty for both tested encoders:

$u_{C\ Encoder1} = \pm 0{,}03$ mm
$u_{C\ Encoder1} = \pm 0{,}04$ mm

These obtained values of uncertainties can be used for declaration of measurement on these tested encoders.

5 Conclusion

The Expanded uncertainty is expressed as combined uncertainty multiplied by coverage factor.

Every measurement has to include also expressing of uncertainty. It describes how we can believe to results of measurement. Measurement without declaration of uncertainties are valueless [3-29].

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