Prototyping of flexible capacitive encoder with un-tethered slider using electrostatic induction

Fumitaka KIMURA, Masahiko GONDO[+], Norio YAMASHITA, Akio YAMAMOTO, Toshiro HIGUCHI

Department of Precision Engineering, School of Engineering / The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656 / Japan, k-bunbun@aml.t.u-tokyo.ac.jp

[+]SEIDEN Corporation, 5-4-21 Nishi-Hashimoto, Sagamihara-city, Kanagawa / Japan

Summary

This paper describes a capacitive encoder that is characterized by its wireless sensor slider. The main components are made as flexible printed circuit films which thickness is only 0.2 mm. Hence, the sensor can be set up in thin interspaces or on curved surfaces. The sensor consists of a long receiver film and a short transmitter film, respectively containing four-phase and two-phase electrode. The transmitter is used as a slider and the receiver is used as a stator. To realize an un-tethered slider, the sensor employs a unique approach; electric power is supplied to the transmitting electrodes by electrostatic induction, thus removing electric wires from the slider. This un-tethered slider can facilitate the sensitive applications where mechanical disturbance caused by an electric wire can be a problem. The principle was verified by a prototype sensor, which showed a linearity error of +/- 4 micro meters.

Motivation

Typical encoders have cabling for a sliding part. For example, an optical encoder typically has a fixed optical scale and a pair of transmitter and receiver as a sliding part[1]. A typical capacitive encoder utilizes one side as a transmitter and the other side as a receiver, both requiring cabling[2]. The cablings in sliding parts can cause mechanical disturbances, which can be a fatal problem for some sensitive applications. In our novel approach[3], the transmitting sensor electrode, which functions as a slider, is energized by electrostatic induction, which realizes an un-tethered slider (see Fig. 1).

Results

An experimental prototype was fabricated as shown in figures 2 and 3. Both the transmitting and receiving electrodes are made as flexible printed circuit films; hence they are mechanically flexible. Both films contain induction electrodes and multi-phase electrodes. The two-phase transmitter (slider) electrode has a pitch of 400 μm and the 4-phase receiver (stator) electrode has a pitch of 200 μm, so that the cycles of electrodes become identical. The two-phase transmitting electrodes are energized to have sinusoidal voltages, which are detected by the receiving electrodes to give position-modulated signals. By demodulating the signals, the slider position is calculated. The key feature of this setup is that the transmitting electrodes are energized by electrostatic induction. The power source is connected to the induction electrode on the stator film. Then, the power is transmitted to the slider through the capacitance of induction electrodes.

The detected signal repeats every 800 μm of the slider displacement. The prototype detecting circuit interpolates it by a factor of 1024. Resultant resolution is approximately 0.8 μm. Figure 4 shows the output of the detecting circuit when the sensor slider moved at a constant speed. Figure 5 evaluates the linearity error by comparing the output with a commercial optical encoder. The result shows that the estimated linearity error is about +/- 4 μm.

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[1] J. R. Rene Mayer, "The Measurement, Instrumentation, and Sensors Handbook", Springer with CRC PRESS and IEEE PRESS, p. (6-98) - (6-119), 1999

[2] David S, Nyce, "Linear Position Sensors", Wiley-IEEE, p. 151-161, 2004

[3] Masahiko Gondoh, "United State Patent", US 7,199,727 B2, 2007

Figures

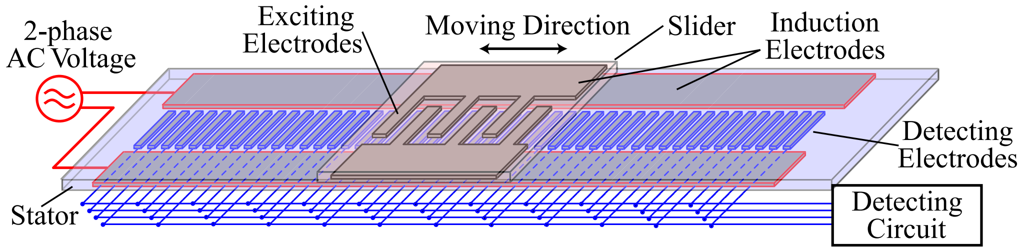

Fig. 1: Schematic diagram of electrostatic capacitive encoder

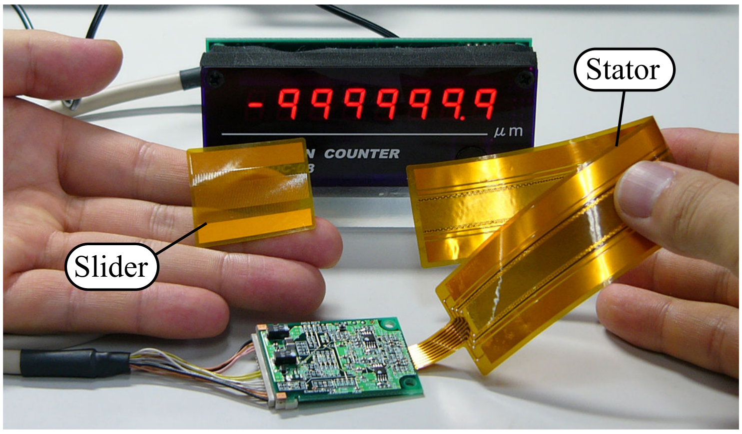

Fig. 2: An experimental prototype with a wireless slider and a wired stator. The electrodes are made by flexible printed circuits

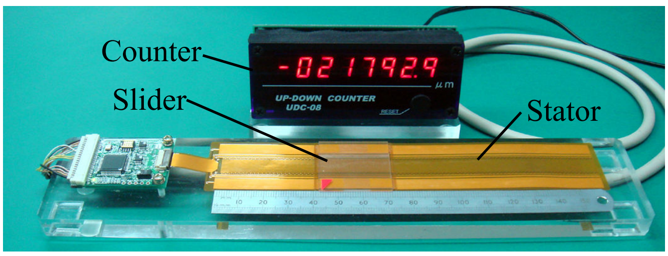

Fig. 3: Experimental prototype in operation

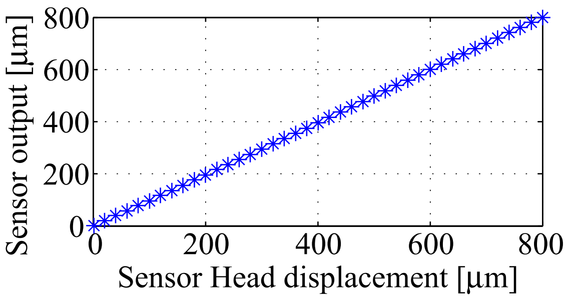

Fig. 4: Output of the encoder at a constant moving speed

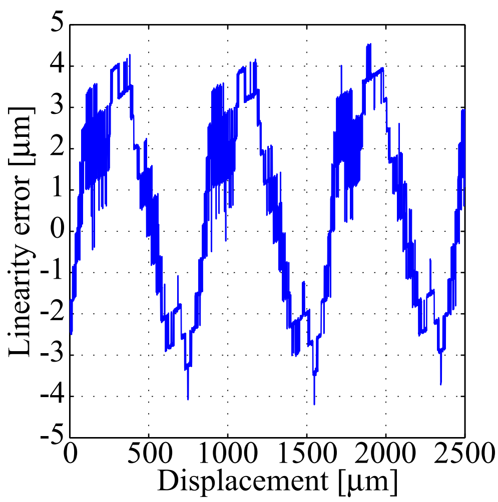

Fig. 5: Linearity error by comparing the film encoder with an optical encoder