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Linear displacement measurement by a microcontroller based system

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The paper describes the way of a system dimensioning required to achieve a linear displacement measurement. The system is based on a microcontroller and an incremental encoder. Taking into account the needing of electronic parameter adaptation at the interfacing of the incremental encoder and the microcontroller, a constructive-functional optimization is accomplished. The sensibility of displacement measurement is given by the number of pulses per angular unit, the microcontroller processing and counting speed as well as the efficiency of implemented algorithm and source code. At the dimensioning of electronic circuit is also requested to consider the possibility of perturbation inducing due to the electromagnetic interference of own sources or from environment.

Keywords*: constructive-functional optimization, displacement measurement system, hardware interface, incremental transducer, microcontroller based system*

1. Introduction.

A wide range of technological processes use as a process parameter or within the process the measurement of linear displacements. The measurement can be done directly, when using a transducer that involves the direct transformation of the linear displacement into a scaled size, or indirectly, when the linear displacement is transformed into a rotation and then scaled [2, 4].

As architectures of the measurement systems, the following can be used: mechanical - mechanical with proportional scaling, mechanical - analogical electronics, mechanical - digital electronics, mechanical - optical (infrared or laser) - digital electronics or optical - digital electronics [1, 3].

The measurement system can be used as such, for the direct display of values, or integrated in a complex architecture of measurement and diagnosis, or integrated in a system of automatic regulation of a process. The degree of integration is reflected by the flexibility of transmission of the measured values. That is, the possibility of a measurement system being able to transmit values through different serial communication strategies with wired, radio, WiFi, ethernet or even via mobile communication, it makes the system much more flexible. Of course, all these facilities make the resulting purchase price quite high [5, 6].

Besides the direct parameters of the measurement, the measurement systems can also be differentiated by the safety in operation, when we speak of critical working environments, which involve: vibrations, corrosive substances, high temperatures, electromagnetic radiation [2, 4]. To solve these problems, the designers of these systems have built increasingly complex functional structures, which include: low working voltages, low energy consumption, independent sources of energy and partial or total energy independence. Also, in such cases data transmissions without electrical connections are used [1, 3].

The system proposed in this paper is part of the mechanical - optical - numerical electronic architecture, following the combination of an incremental sensor with a microcontroller [5].

2. Incremental transducer interfacing

The incremental transducer sensor (IT) interface strategy results from the technical characteristics offered by it, regarding the transmission of the measured values. The type of IT used in this linear displacement measurement system (LDMS) is I / 45CC-2000-5-BZ-N-CV-R-01. It has the following characteristics [9]:

I - incremental rotation transducer;

45C - model;

C - 16-tooth sprocket;

2000 - pulses per full rotation;

5 - DC voltage supply level 5 Vdc;

BZ - bidirectional + 0;

N - electronic with driver 26LS31, generates three pulses on each pulse, each on a separate differential output (A +/-, B +/- and C +/-);

CV - cable 1 m long and 9 wires;

R - the maximum switching frequency of the logic levels at the output 75 kHz.

For each of the 2000 pulses, three pulses with 120 electric degrees phase shift are generated, corresponding six changes of the logic levels, and resulting in a significant increase in the measurement accuracy.

The rack used to convert linear displacement into rotation angle is of type L / CR80-1000-5-BZ-N-5-4-CV-R-01 [9]. Thus, the combination of the two results in a complete rotation of the pinion for the unit of length Ul = 20 mm linear displacement.

The linear displacement unit (Ld) for a pulse can be calculated:

$$Ld = Ul / 2000 = 10\ [\mu m]$$

Thus, a minimum displacement (Dm) possible to measure results:

$$Dm = PP / 6 = 1.(6)\ [\mu m]$$

In order to eliminate the possible measurement errors, after each complete pulse, the state of zero can be detected, and thus the reset of the small errors accumulated during the period of a pulse.

Figure 1 shows the constructive-functional aspects and the mechanical assembly of the two components of the linear displacement transducer [9].

Figure 1. Incremental transducer sensor assembly.

For processing the signals acquired from the incremental transducer, as well as the LCD display of the value of the displacement size, we will use the microcontroller PIC16F877. The PIC16F877 microcontroller can be found in two constructive variants: with 28 or 40 pins. It can operate with 8- or 16-bit registers and values, has an 8 kB on 16-bit FLASH memory, 368 kB on 8-bit RAM, 256 kB on 8-bit EEPROM data memory, touch frequency 20 MHz maximum, two 8-bit and 16-bit timers, 10-bit digital analog converter [7, 8].

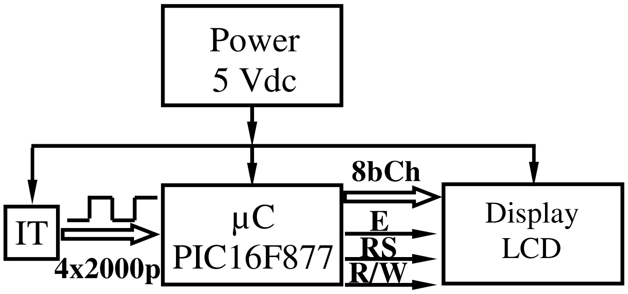

Figure 2. Functional block diagram of LDMS.

The functional block diagram given in figure 2 helps to build the LDMS, and the meaning of components and parameters is:

5 Vdc - 5 V stabilized DC source;

IT - incremental encoder with 3 differential outputs;

μC (PIC16F877) - 8-bit microcontroller with values extending up to 16 bits.

LCD display - 2-row liquid crystal display, each with 20 characters;

8bCh - the encoding of the displayed characters is done on 8 bits and ASCII coded;

R / W - read / write the display;

E - it enables the reception of a transmitted character;

RS - display reset.

3. Algorithm description

The schematic of the logic algorithm (flowchart from figure 2) helps in the realization of the source code, due to the representation of all the stages of the functional process and the interdependencies between them.

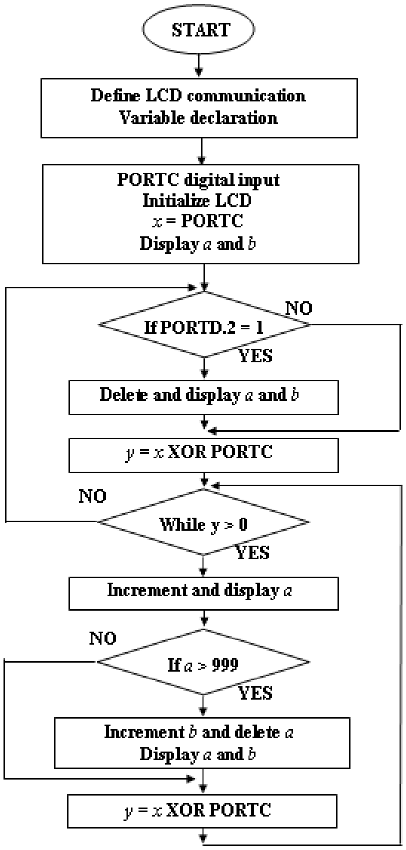

Figure 3. Flowchart for LDMS.

The implementation of the flowchart was made in Basic Compiler, which is a way of source code compilation, from PIC Simulator IDE interface.

4. Device development

The LDSM basically consists of a microcontroller and an incremental displacement transducer. Based on them, the LDSM device was developed, and the important constructive and functional aspects are depicted in figure 4 and short details about them are given below:

uC - PIC16F877 microcontroller;
TR - 230 / 7.5 Vac and 7 W transformer;
VS - voltage stabilizer 5 Vdc / 0.8 A;
SC - incremental sensor connector;
DC - display connectors;
LCD - display module;
RV - reset of displayed values;
DB - adjust the display brightness;
RS - the general reset of the equipment.

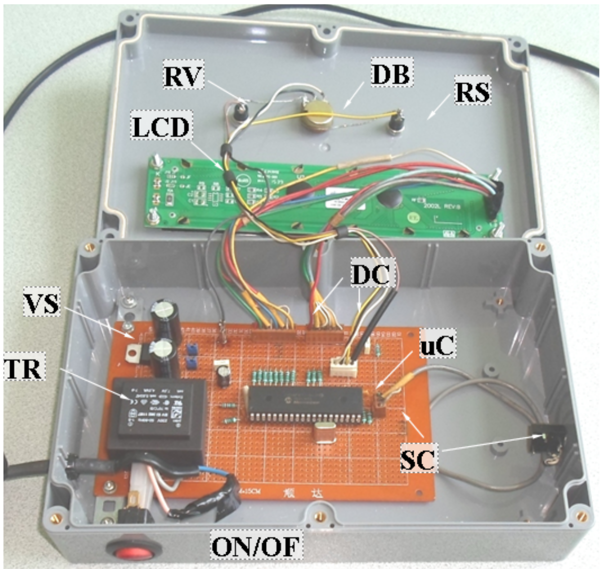

Figure 4. Flowchart for LDMS.

Some tests were performed to check the LDSM performance and they consisted of fixing distances for different displacements and verifying the achieved values by using the designed equipment.

5. Conclusion

The measurement accuracy predicted in this state of system development is approximately 10 µm. Due to its flexible structure the designed measuring system has the flexibility and adaptability for easy integration into other measuring diagnostics or automatic adjustment systems. By attaching a communication module, the system can transmit the measured values via Bluetooth, WiFi, internet or mobile communication.

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