Abstract – Determining the position is one of the important requirements of the mechatronic systems. Various types of transducers and different types of solutions are used to determine the position, among which the most advanced are the ones based in the optical principles. The optical systems allow determining the position in more coordinates and have the advantage of a high accuracy in conditions when direct contact is avoided.

This paper presents a few solutions for determining the position by using electronic system usually used at the mouse device.

The main advantages of such a system are the high accuracy (which is steadily growing), determining the position in two coordinates, very low mechanical wear, the low price, digital processing of information. The main disadvantage of such a system is the fact that the sensor requires a perfectly flat surface and a particular type of surface. The solutions currently used are applied for different types of robots that can move on flat surfaces.

This paper presents a solution for the positioning of a stand in which the sensor is positioned on the opposite surface of the active surface. In this way you can ensure the necessary conditions to protect the sensor, and the necessary quality of the surface needed by it. This way, the active surface can be used for different purposes, because the surface is not necessarily flat (e.g. holding devices).

Another solution presented is that of a positioning system for two mechanical hands designed for manipulating pieces on a chessboard. Such a system provides three axis of reference, the sensor being placed on hand tools.

The signal from the optical sensor is taken over by a computer system built with a microcontroller. The micro system provides the signal processing and develops the controls for the actuators.

Keywords – mechatronic systems, transducer, optical measuring system

1. INTRODUCTION

The optical system used for determining the position of the mouse type devices has many advantages in establishing the position in the plane [1] [2]. The provided resolution is high, currently leading to resolutions of 4000 dpi (dots per inch). The optical system for determining the position contains no moving mechanical parts and therefore has a high reliability [3] [4]. Because the signal is transmitted serially, wireless connections (Wireless) can be easily made. The disturbances’ influence on the position transducer is very small. The data are provided in digital format, which allows direct connection to a computer system. The computer system can diagnose and track the status of the position transducer.

The main disadvantage presented by such a system is that the surface on which the position transducer moves should be flat and have certain features for the best possible results.

Hereinafter, a few solutions for using this type of position transducer will be present [5].

In Figure 1, the position transducer is mounted on the movable element. This way, on the top surface of the movable element, holding devices or other items can be mounted. The fixed surface is flat and properly processed as for the optical position transducer to function properly. For this version, the fixed surface has to be protected from any contaminants that may reach the movable element, with protective aprons or movable protection casing.
In Figure 2 the optical displacement transducer is mounted on the fixed element. For this solution the lower surface of the movable element has to be properly processed for the optical position transducer to properly function. The upper surface of the movable element must not be flat and on this surface various components can be mounted (e.g. holding device). The flat surface need not be flat.

For this solution, the optical position transducer is better protected from any impurities that may fall on the active surface.

The solutions shown in Figure 1 and Figure 2 can be applied to a single coordinate movement or a displacement on two coordinates. Also, between the movable element and transducer a pantograph type device can be inserted. This allows for increased/decreased of the amplitude motion with direct impact on the resolution. The addition of a pantograph-type device also allows the mounting of the optical position transducer in a protective area. Based on this idea, hereinafter, a variant of the mechanical hand is presented.

Figure 3 presents the solution of a manipulator that can move in three coordinates. This handler is used to move chess pieces on the board, but it may have other similar applications.

The manipulator shown in Figure 3 is based on the pantograph. In the point P is a mechanical arm that allows grabbing the pieces on the chessboard. The mechanical arm can move in three axes of reference by operating in two points. On the z-axis, the movement is made between two fixed positions by operating in the O point with the help of a pneumatic device or relay. Thus, on the z axis, the mechanical hand can only have two positions: "high" when the mechanical hand is moving over the chessboard and "low" when the mechanical arm grabs and places a chess piece on the board.

The movement in the xOy plane of the mechanical hand is made by operating point D. The amplitude of the point D motion increases at the P point by the following equation (Eq. (1)):

\[
\frac{OB}{OA} = \frac{OP}{OD} = k = const \tan t
\]

where OA, OB, OP, DO are segments defined in Figure 3.

The optical position transducer found in the D point provides the information of the plane position. According to Eq (1) the resolution of the optical position transducer should be relatively high for the positioning accuracy of point P to be good.

The advantage of the solution lies in the separation of the action field position of the mechanical hand from the measurement field.
2. The operating principle of the optical position transducer

As it was shown, the optical device for determining the position is actually a mouse type device [6]. Such a device is used due to the optical system already installed, although such a construction is easily achieved. The manufacturer provides the user with all components and all the necessary documentation to make such a device.

The optical system for determining position comprises of two integrated circuits and a minimum number of components. One of the integrated circuits is the optical sensor and the other one is the DSP (Digital Signal Processor). The communication between the two circuits is done by a SPI serial interface (Serial Peripheral Interface). The DSP circuit communicates via a USB interface (Universal Serial Bus) or via a PS/2 (Personal System/2 - IBM) with another computer system [7].

The optical sensor is a complex integrated circuit that has several functions. The main function is to capture an image obtained through reflection with the use of an image processor. The light source for obtaining the image is a LED (Light Emitting Diode) or a laser diode. The image processor (which works like a video camera) acquires images with a relatively low resolution and compares them in order to find meaning and the amplitude of the movement. The amplitude of the horizontal and vertical movement is quantified and stored in two registers: “Delta_X” and “Delta_Y”.

Such an image processor can capture a variable number of frames in a second in order to adjust to the movement speed (e.g. the frame rate may vary between 1000 and 6400 fps - frames per second). The distance between lens of the optical system and the surface has to be 2.5 mm. The resolution of such an image processor can reach 1600 cpi (counts per inch) indicating the number of increments or decrements performed on the records Delta_X and Delta_Y when the sensor is moving 25.4 mm (1 inch).

The image processor is a programmable device, the company producing providing the appropriate programming software and subsequent updates. The programming of the device is done via a serial SPI interface and the work methods are established through image processor's internal registers. The main modes are: the reading of the state of the image processor, its configuration, the reading of the data corresponding to the movement and the reading of the acquired image data.

The DSP circuit that connects to the image processor is an 8 bits RISC (Reduced Instruction Set Computing) microcontroller. The main tasks of the DSP circuit are the programming and configuration of the image processor and providing the interface with the computer through the USB interface or PS / 2. The DSP circuit controls the optical image processor and process its displacement information.

Figure 4 presents the schematic diagram of the optical system for measuring displacement.

This system is taken from a mouse device and is adapted to the solutions presented in Figures 1-3.

![Figure 4: The schematic diagram of the optical measuring system](image)

The protocol used for the DSP circuit interface with the computer is what interests the user. The application presented in this article uses the PS/2 interface because this one is easier to connect to a general-purpose microcontroller.

The PS / 2 interface is a serial interface which allows the information transfer bit by bit. It is used for both the command and the control of the optical measuring system and for reading the data supplied by it. The information circulates both ways between the optical measuring system and the computer connected to the PS/2 interface establishing a dialogue under the PS/2 protocol standard.

The physical connection PS / 2 requires three connections: a data link (Data) which is bi-directional, the information moving on this connection both ways, a bi-directional Clock connection which is the synchronization signal for the data signal and a Ground signal connection. It follows therefore that the PS / 2 interface is a synchronous, bi-directional serial connection. The clock signal is generated by the data sending device, the receiving device using the clock signal to synchronize the data signal.

Hereinafter, the optical measuring system will be referred to as "device" and the computer system to which it is connected as "host". The PS/2
protocol uses data package of eleven bits with the following structure: one star bit, eight data bits, one bit of parity and one stop bit (Figure 5).

![Figure 5: The structure of the data package](image)

Under the application of power or at the activation, the device sends the host two bytes of data.

<table>
<thead>
<tr>
<th>Bit 7</th>
<th>Bit 6</th>
<th>Bit 5</th>
<th>Bit 4</th>
<th>Bit 3</th>
<th>Bit 2</th>
<th>Bit 1</th>
<th>Bit 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y overflow</td>
<td>X overflow</td>
<td>Y sign bit</td>
<td>X sign bit</td>
<td>Always 1</td>
<td>Middle Btn</td>
<td>Right Btn</td>
<td>Left Btn</td>
</tr>
</tbody>
</table>

| Byte 1 | X Movement |
| Byte 2 | Y Movement |

The first byte contains information about the direction of movement of the device from its previous position, about overcoming the value of the byte two and three and about the mouse buttons positions (not used in this application). The two and three bytes provide information on the movement of the device on the x-axis and the y-axis. The values of the two and three bytes are calculated based on the values of Delta_X and Delta-Y registers from the image processor.

In order to be able to use the displacement information provided by the optical measuring system shown in Figure 4 for the control of the mechatronic systems, an electronic circuit provided with a 16F876 Microchip microcontroller was developed.

### 3. The circuit diagram of the computer system

The optical displacement measuring system is connected through the PS/2 interface to a computer system developed with a microcontroller.

The circuit diagram of the system is shown in Figure 6. This figure, the integrated circuits are represented by: U1, the 7805 5V voltage stabilizer for feed through; U2, the Microchip PIC 16F876 microcontroller, U3, the MAX232 circuit for transmission / reception and U4, the 4050 serial bi-directional buffer circuit.

In addition, the circuit contains a keyboard with 12 keys, a LCD (Liquid Crystal Display) display circuit, a J1 PS / 2 connector for connecting to the optical system for determining the position (mouse type device), a J2 DB-9 type nine-pin connector for connecting to the serial interface compatible with the standard RS232, a J3 connector for connecting to the control drives on the X, Y and Z axis, a system initialization button (RESET), a contact for system origin referral (ORIGIN) and a piezoelectric speaker for acoustic signals.

The main circuit, the PIC 16F876 microcontroller, has the following main features (used in this application): a RISC central unit with 35 instructions which are executed in one machine cycle, 8 K Flash memory program words, 368 bytes SRAM (Static Random Access Memory), 256 bytes EEPROM, 22 digital I / O, a USART (Universal Asynchronous Receiver Transmitter sync) serial interface, timer circuits and a cutting edge interruption system. It must also be noted that the microcontroller contains a number of additional modules that have not been used in this application and therefore were not mentioned here.
The MAX232 integrated circuit ensures the appropriate voltage levels (±12V) for the serial communication as the RS232 standard states.

![Circuit Diagram]

**Figure 6:** The circuit diagram of the micro system

The microcontroller ensures the dialog between the mouse type device and it receives the displacement information provided by the PS / 2 standard. Because the inputs / outputs of the microcontroller are not bi-directional it was necessary to use the U4 buffer circuit to adapt them to the "DATE" and "CLOCK" lines. The "CLOCK" signal, which reaches the microcontroller at the PORTB.7 entrance, causes a disruption. In the interruption routine, the incoming data from the „DATA" line from the optical circuit are synchronously read in order to determine the position.

The keyboard of the micro system allows the entering of the local commands and of the coordinates for the positioning system. The LCD display system consists of a 2x16 character screen that allows the display of local messages with information on the operation and positioning.

The actuators command on each axis is done through the "RL1", "RL2" and "RL3" relays. The control of the relays is done through the “Q1”, “Q2” and “Q3” transistors that are connected to the digital outputs of the microcontroller. Their internal timers of the microcontroller control these outputs so that appropriate positioning commands can be generated.

The circuit is powered by 12 DC unstabilized V and 5V DC stabilized 5 V by the U1 circuit.

The microcontroller is provided with a program that operates in real time to ensure the proper implementation of the tasks set.

4. The micro system program

The micro system with the PIC 16F876 microcontroller is programmed to operate independently or connected to a PC (Personal Computer) through a serial interface. The program was written in MikroBasic.

Hereinafter, the application made for the chess player handlers will be described below, because this application also covers the other ways being the most complex.

The micro system program must fulfill several tasks. Of these, the main tasks are:

- to run self-testing and self-diagnosis sub programs at startup and initialization and to display the information on the LCD device;
- to provide command and control optical measuring system;
- to provide closed loop control of the positioning system for the x and y axis and to order the z axis;
- to ensure local dialogue with the operator through a command language;
- to ensure dialogue with the superior system, the PC computer.
The micro system program has only one main interruption caused by the incoming clock signal from the optical positioning system. In this interruption working with the optical positioning system is ensured. The interruption works as a finite-state machine providing a certain state of the optical positioning system for certain input combinations.

The main combinations are:
- boot device - be it at the beginning of the session or when it reaches the origin;
- scheduling the parameters for reading the position – is done after initialization or when changing the resolution;
- reading the coordinates – is done at the automatic positioning or in the learning phase.
- the control of the positioning is done by the micro system in three different cases:
- when the micro system is working independently, the user enters the coordinates of the point, after which it performs in closed loop positioning;
- when the micro system works connected to a superior system such as a PC, the coordinates are received from the computer, the micro system ensures the positioning and signals the moment the action is concluded through the serial interface.
- in the learning phase when the micro system is connected to a PC. The positioning is done manually, and the coordinates are sent via the serial interface to the PC through a command from the micro system keyboard.

The position controller programmed for the micro system can calculate simple interpolations to reduce the positioning time. For complex movements, the micro system has to work connected to a superior interface through the serial interface.

In this version, the positioning in the xOy plane is done when the manipulator is on the z-axis in the "up" position. After the positioning, the arm is lowered and its moving in the xOz plane is no longer possible.

The dialogue with the local operator is similar to that done by the serial interface with the superior system. Due to the limited possibilities offered by the local keyboard of the micro system, the structure of a command line was as a combination of its characters.

The command begins with a "#" character followed by two digits. This way, 100 separate commands are possible, which amply covers the requirements for micro system command. The command itself may not have any operand or may be followed by one or more operands also separated by the character "#". The command termination character is "*". An example of a command string can be: # 07 # 137 # 028 *. The commands entered are shown locally on the LDC. The coordinates’ values are entered in millimeters. The commands sent via the serial interface are ASCII (American Standard Code for Information Interchange) character strings for enabling the use of the common PC communication programs.

5. Conclusions

This paper presents a positioning system with a mouse type device for a mechatronic system. For using a mouse type device, a 16F876 PIC microcontroller that can be connected to a superior computing system was developed and programmed.

The performed experiments lead to the following: the obtained results are very good, the system ensuring the correct positioning and the possibility of training. Thus the system can be taught to perform certain predetermined movements. Another advantage of the system is that the determination of the origin has to be done only at the beginning. The coordinates kept a relatively long time allowing the system to recalibrate only when the movements require passage through the origin.

However, the system cannot ensure the proper positioning for precision work. But, the low price and its simplicity of use are still making this system useful for the mechatronic positioning systems.

6. References