DIGITAL SYSTEM FOR OPTICAL INCREMENTAL ENCODER CONNECTION

Fl. GROFU[1], Luminița POPESCU[2]

Atunci când este necesară monitorizarea mişcării mecanice de rotaţie encoderele sunt cele mai importante interfeţe între partea mecanică şi unitatea de control. Encoderele transformă mişcarea de rotaţie într-o secvenţă de pulsuri electrice. Conectarea encoderelor într-un sistem de automatizare se realizează prin intermediul unui sistem numeric capabil să detecteze incrementul rotaţiei şi direcţia de rotaţie. De asemenea sistemul are posibilitatea de conectare la un sistem de comunicaţie pentru transferul de date la un dispecer central.

Whenever mechanical rotary motions have to be monitored, the encoder is the most important interface between the mechanics and the control unit. Encoders transform rotary movement into a sequence of electrical pulses. The connection of the encoders to an automated system is made through a digital system, which is able to detect the increment and direction of rotation. Also, the system has the possibility to connect to a communication system for the data transfer with a central dispatcher.

Keywords: digital system, automatization, incremental encoder.

1. Introduction

Optical rotary incremental encoders consist of five main components: LED light source, rotating code disk, stationary mask, photodetector(s), amplifying/squaring electronics. As the code disk rotates in front of the stationary mask, it shutters light from the LED. The light that passes through the mask is received by the photodetector, which produces pulses in the form of a quasi-sine wave. The encoder electronics convert the sine wave into a square signal, ready for transmission to a counter. The basic structure of an incremental ecoder with conventional code disc is show in Fig.1.

Conventional incremental code disks contain a fixed number of equally spaced opaque lines that produce a corresponding number of pulses per revolution. The position and spacing of the lines on the disk requires a high degree of precision. Physical limitations determine the maximum number of lines that can be created on a code disk of a given size. A single channel incremental encoder, or tachometer, is used in systems that operate in only one direction and

[1] Eng., Lecturer, Dept. of Automation, “Constantin Brancusi” University Tg-Jiu, Romania E-mail: florin@utgjiu.ro
[2] Eng., Prof., Dept. of Automation, “Constantin Brancusi” University Tg-Jiu, Romania

require simple velocity information. Velocity can be determined from the time interval between pulses, or by the number of pulses within a given time period.

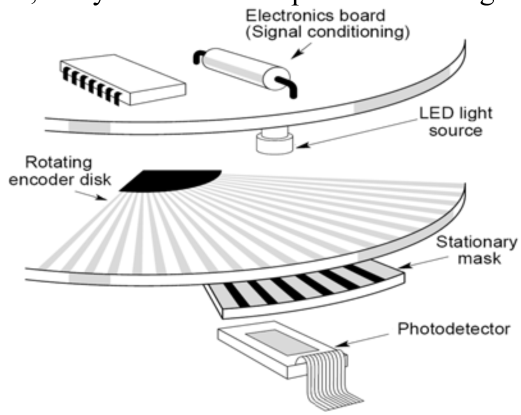

Fig.1 Basic structure of an incremental encoder

Quadrature encoders have dual channels, A and B, which are electrically phased 90° apart. Thus, direction of rotation can be determined by monitoring the phase relationship between the two channels. The most popular of the encoders is the incremental TTL type. The output is a digital pulse train with varying resolutions. Encoder resolutions of 50 - 5,000 lines per revolution are standard from most vendors. Special line counts up to 100,000 are also available. From these reasons, the authors have built a digital system witch is capable to read information from an optic encoder and then to send it online in to an informatics network using the RS485 interface.

2. SYSTEM DESCRIPTION

2.1. System’s needs

The system presented in this paper has as purpose the interconnection of the incremental encoder into a modern automated system, as shown in Fig. 2.

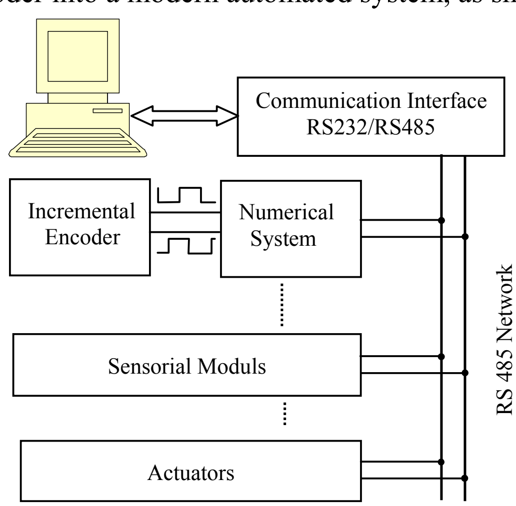

Fig.2 Automation system

According to the above, interconnecting different modules from the automation chain is made using the RS485 communication network on two wires. To this end, each module has an address for identification allocated, and the communication between the modules is of the multiprocessor type, so that in the case of transmitting a package of data, it will only be received by the module whose address is equal to the address of the package of data.

2.2. System's description

The proposed digital system for the connection of the incremental encoder is one with two microcontrollers, being able to ensure a safe and correct decoding of the signals received from the encoder to determine the rotation way and the relative movement.

Also, the system is able to memorize the last position, to make the communication with a dispatcher, to initialize with a corresponding value to a certain movement.

The system can also be made with only one microcontroller which must accomplish at the same time all the desideratum. In case the system is used in an automation chain, it is required that a safe communication and functioning with the dispatcher regarding the reaction, and also a correct determination of the movement parameters.

In case of a large number pulses per revolution and of high rotation speeds, the duration of the impulses which result at the output of the encoder is rather small. That is why it may happen that during a communication interruption and its solving, some information can be lost about the movement of the encoder (impulses or states).

An easy way to separate the two job is to make a simple module with microcontroller for each one. The two modules are connected between each other through a very fast parallel interface, so that the data exchange to be made very fast. The two modules, master for communication and slave for the information processing must fulfill the following functions:

The slave module

- takes over the signals from the incremental encoder;
- analyses those signals to determine the movement way;
- incrementation or decrementation of the position counter according to the movement and number of resulted impulses;
- the fast data transmission towards the master module in case of an interrogation;
- reading, just after reset of the EEPROM memory and initializing the position counter with this value.

The master module
- on start, it ensures the reset of the slave module;
- communicates with the dispatcher with the recognition to the base of a local address of the data package which is destined to it;
- makes the interrogation of the slave module and reads the current position of the counter;
- saves in the EEPROM memory the data read from the slave module;
- saves in the EEPROM memory the initial value received from the dispatcher and resets the slave module ;
- saves in the EEPROM memory the new address of the communication module in case it is modified by the dispatcher;

The general structure, proposed by authors, of the digital system of connection of the incremental encoder is shown in Fig. 3.

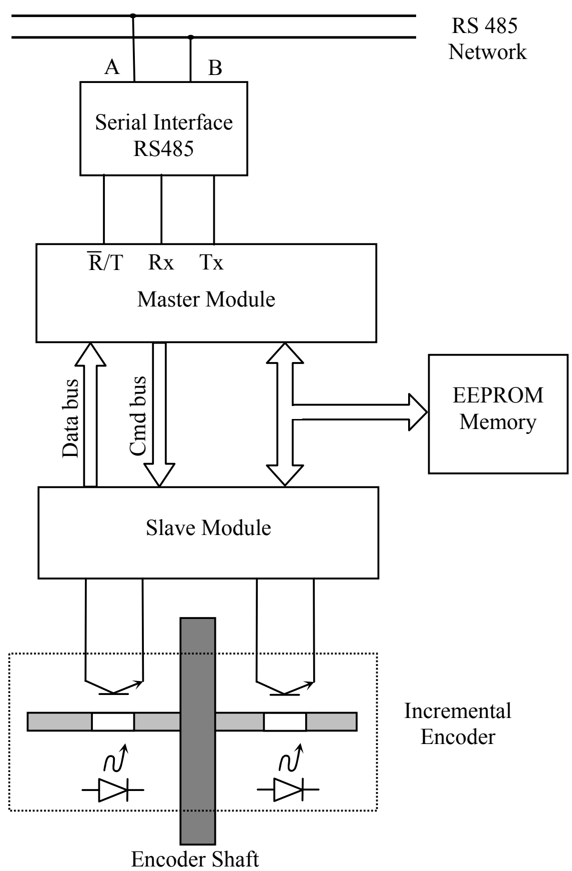

Fig.3 The structure of the digital system

2.3. System's operation

The communication part has the possibility to allocate dynamically the working address. At the first connection, all the systems have the same base address 00H. Immediately after connecting to the RS485 network the module's address is modified according to the configuration of the automation installation. It is important that at a certain moment, two modules shouldn't be connected with the same address and neither to be allocated an already existing address to a module.

When the digital system for the connection of the incremental encoders starts, the master module commands the reset of the slave module. Slave module just after reset reads the EEPROM memory for initializing the position counters.

During working, the master module interrogates the slave module to read the current position. The read value is then saved in the EEPROM memory. To initialize the system for a certain position, a command from the dispatcher is given to initialize and also the dispatcher gives a value for the position counter. The master module receives the data package and saves in the EEPROM memory the value for initialization, and then commands the reset of the slave module which will be initialized with the value contained in the EEPROM memory.

To make the master and slave modules, the AT89C2051 microcontroller is used.

The AT89C2051

The AT89C2051 is a low-voltage, high-performance CMOS 8-bit microcomputer with 2K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C2051 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

The AT89C2051 provides the following standard features: 2K bytes of Flash, 128 bytes of RAM, 15 I/O lines, two 16-bit timer/counters, a five vector two-level interrupt architecture, a full duplex serial port, a precision analog comparator, on-chip oscillator and clock circuitry. In addition, the AT89C2051 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning. The power-down mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset.

The serial port of AT89C2051 is full duplex, which means it can transmit and receive simultaneously. It is also receive-buffered, which means it can begin receiving a second byte before a previously received byte has been read from the receive register. (However, if the first byte still has not been read when reception of the second byte is complete, one of the bytes will be lost.) The serial port receive and transmit registers are both accessed at Special Function Register SBUF. Writing to SBUF loads the transmit register, and reading SBUF accesses a physically separate receive register. The serial port operate in the following mode. 11 bits are transmitted (through TXD) or received (through RXD): a start bit (0), 8 data bits (LSB first), a programmable ninth data bit, and a stop bit (1). On transmit, the 9th data bit (TB8 in SCON) can be assigned the value of 0 or 1. On receive, the 9th data bit goes into RB8 in Special Function Register SCON, while the stop bit is ignored. The baud rate is variable **.**

Transmission is initiated by any instruction that uses SBUF as a destination register. Reception is initiated by the incoming start bit if REN=1.

Multiprocessor Communications

In this mode, 9 data bits are received, followed by a stop bit. The ninth bit goes into RB8. Then comes a stop bit. The port can be programmed such that when the stop bit is received, the serial port interrupt is activated only if RB8 = 1. This feature is enabled by setting bit SM2 in SCON. The following example shows how to use the serial interrupt for multiprocessor communications. When the master processor must transmit a block of data to one of several slaves, it first sends out an address byte that identifies the target slave. An address byte differs from a data byte in that the 9th bit is 1 in an address byte and 0 in a data byte. With SM2=1, no slave is interrupted by a data byte. An address byte, however, interrupts all slaves, so that each slave can examine the received byte and see if it is being addressed. The addressed slave clears its SM2 bit and prepares to receive the data bytes that follow. The slaves that are not addressed set their SM2 bits and ignore the data bytes.

EEPROM memory

The AT24C02 devices are 2048 bits of CMOS non-volatile electrically erasable memory. These devices conform to all specifications in the Standard IIC 2-wire protocol and are designed to minimize device pin count, and simplify board layout requirements. This communications protocol uses CLOCK (SCL) and DATA I/O (SDA) lines to synchronously clock data between the microprocessor and the slave EEPROM device.

Communication RS485

To make the communication in the RS485 network, the SN75176 driver is used. The SN75176 differential bus transceiver is a monolithic integrated circuit designed for bidirectional data communication on multipoint bus-transmission lines. The SN75176 combines a 3-state differential line driver and a differential input line receiver, both of which operate from a single 5-V power supply. The driver and receiver have active-high and active-low enables, respectively, that can be externally connected together to function as a direction control. The driver differential outputs and the receiver differential inputs are connected internally to form differential input/output (I/O) bus ports that are designed to offer minimum loading to the bus whenever the driver is disabled or VCC = 0. These ports feature wide positive and negative common-mode voltage ranges making the device suitable for party-line applications. The driver is designed to handle loads up to 60 mA of sink or source current. The driver features positive- and negative-current limiting and thermal shutdown for protection from line fault conditions. Thermal shutdown is designed to occur at a junction temperature of approximately 150°C.

The complete scheme of the digital system for connection of the incremental decoders, designed and tested by the authors, is shown in Fig. 4.

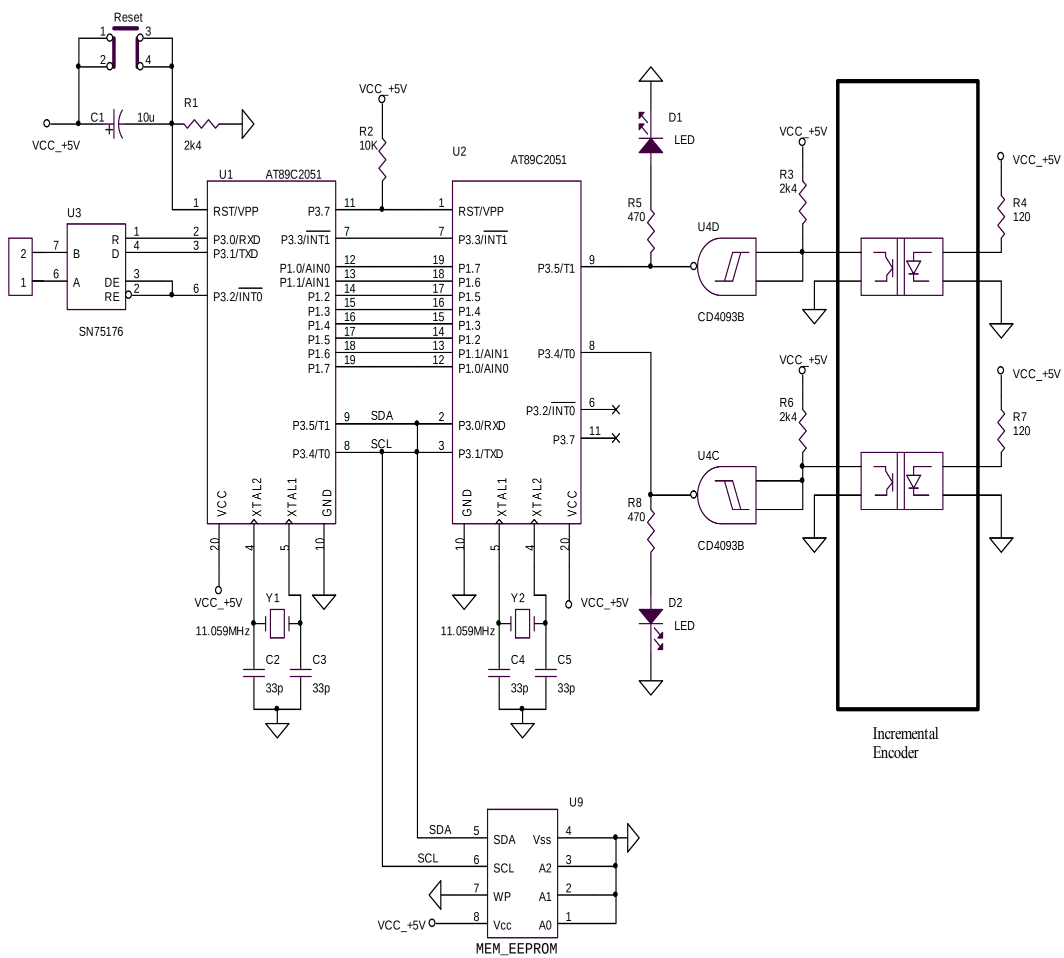

Fig.4 The digital system scheme

This system can be used with any encoders with dual channels, A and B, which are electrically phased 90º apart and have TTL output. Encoder resolutions can be from 50 to 5000 pulses per revolution.

Whereas the detection subroutine of incremental / decremental mode, depend on sense of rotation, during 20 machine cycles max, on a clock signal of 11 MHz result possibility to detect 50.000 increments / decrements per second. If encoder has 5000 pulses per revolution result possibility to detect an angular motion with frequencies 10Hz max. Entire scheme can be integrated in any angular motion detecting application, with accuracy to 0.07º (for encoder with 5000 pulses per revolution).

3. Conclusion

The digital system for connecting optical encoders that was presented is simple and assures a high precision regarding the determination of the parameters for the revolution movement. The possibilities of communication with a dispatcher make this system ideal to be connected into a digital system of automation. The modular structure allows a high flexibility regarding programming the modules in case of adapting the system to other transducers or automation systems. The advantages of this proposed system are: high speed of communication with no influence upon the precision of the optic encoder, hold of the last position in case the system is stopped, possibility of remote initialization with certain value and easy connection in any automated system witch used the RS485 network

R E F E R E N C E S

[1] *Toma Liviu* - Sisteme de achiziție şi prelucrare numerică a datelor, Editura de Vest, Timişoara, 1996.
[2] *D. Marinescu*- Microcontrolerul 80C32 Manual de utilizare, Editura Tehnică, 1998
[3] *Stephen Petronio* (2002). Optical rotary encoder basics -Design News, April 22, 2002 availabe at http://www.designnews.com
[4] Optical Encoder Fundamentals available at http://zone.ni.com/devzone
[5] AT89C2051 and AT89C52 datasheet, available at: htt://www.atmel.com
[6] *J. Axelson*, Serial Port Complete Programming and Circuits forRS-232 and RS-485 Links and Networks, Lakeview Research,Madison, WI, 1998.
[7] TSB89, *Application Guidelines for TIA/EIA-485-A*, www.global.his.com.
[8] Optoelectronics for Mouse and Shaft Encoder Applications, Application Note available at www. honeywell.com