Received: 05 Sep. 2017
Accepted: 17 Sep. 2017

CONDITION OF MEASUREMENT CHAIN WITH LINEAR ENCODER

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Keywords: measurement, calibration, uncertainty, gauge
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].

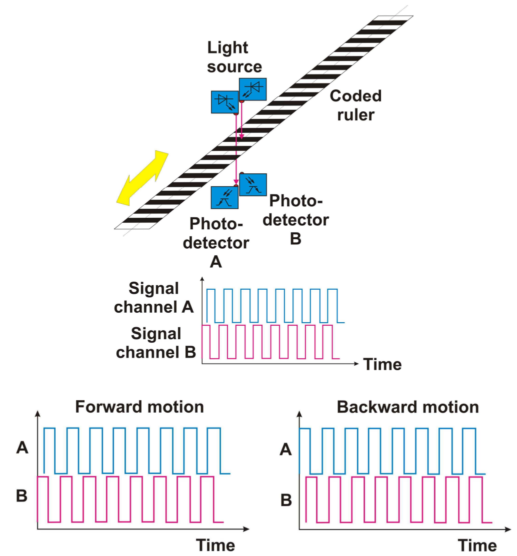


Figure 1 Incremental optical encoder principle and recognition of motion direction of optical incremental encoder

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.

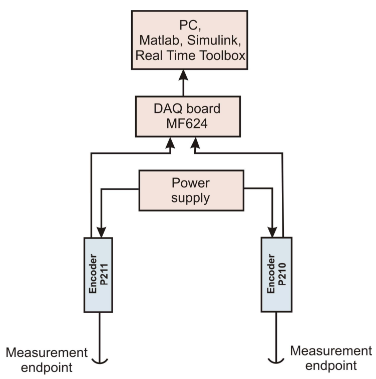


Figure 2 Measurement chain with two tested optical incremental encoders

Acta Mechatronica – International Scientific Journal about Mechatronics
Volume: 2 2017 Issue: 3 Pages: 1-5 ISSN 2453-7306

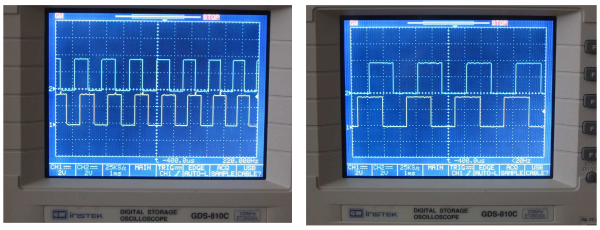
Encoder is made in steel case with same gripping as dial indicator frequently used in dimensional metrology. It means that standard dial indicators stands can be used as holder.

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.

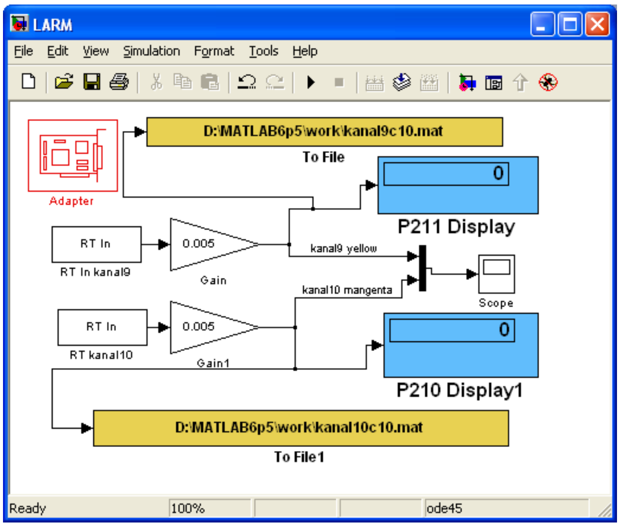


Figure 4 Data processing in Matlab/Simulink

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).

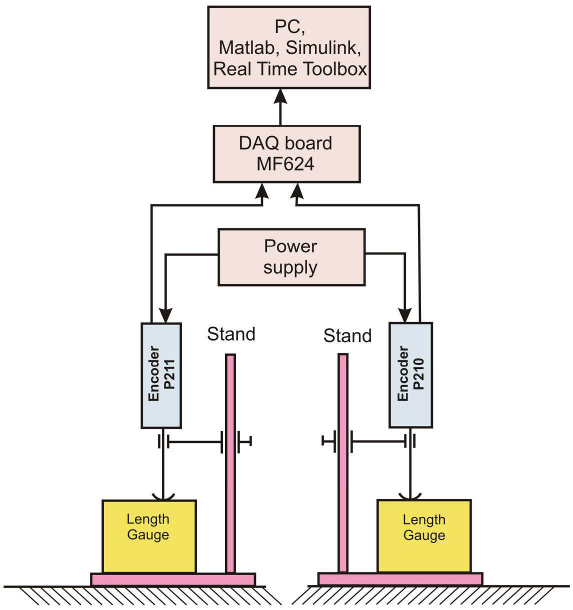


Figure 5 Calibration process structure

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.

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.

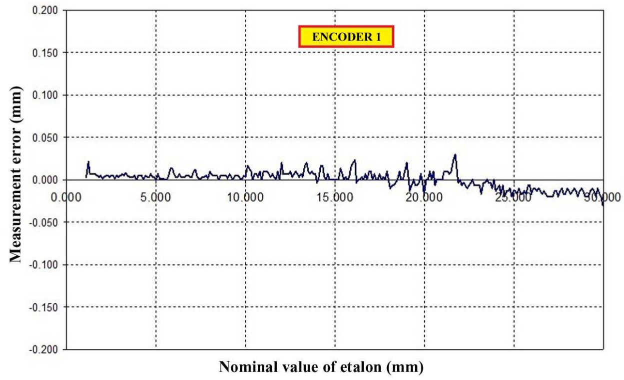


Figure 8 Measured errors on encoder 1

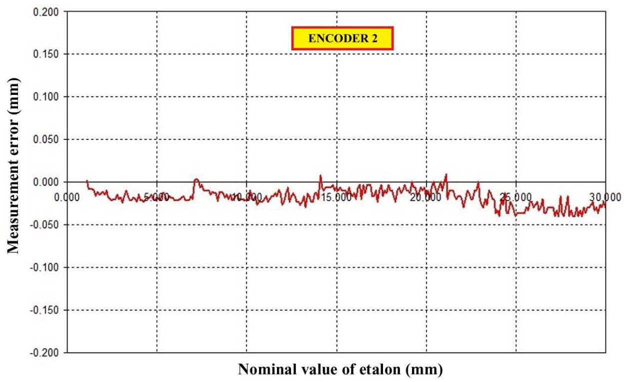


Figure 9 Measured errors on encoder 2

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:

$u_{C\ Encoder1}$ = ±0,03 mm
$u_{C\ Encoder1}$ = ±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].

Acknowledgement
The work has been accomplished under the research project APVV-15-0149 financed by the Slovak Ministry of Education.

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Review process

Single-blind peer reviewed process by two reviewers.

Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 2 2017 Issue: 3 Pages: 7-12 ISSN 2453-7306

Received: 08 Sep. 2017
Accepted: 19 Sep. 2017

MICROCONTROLLER FOR MECHATRONIC SYSTEMS

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Keywords: mechatronics, education, embedded systems, microcontroller
Abstract: The paper deals with microcontrollers, which are as the brain of the mechatronic products. Microcontroller is able to obtain signals from sensors or other devices and it is able to controll actuators or send information to other microcontroller.

1 Introduction

Microcontrollers are belonging to group of embedded systems, which are applicable for control of processes and product functions. This purpose needs to capture information about the product and also about surround. These information's have to be processed inside the microcontroller and after processing the microcontroller makes decision about next steps if it is necessary. Right decision depends on suitable selected sensors and processing of captured information. Data capturing and processing is the main role of microcontroller. Microcontroller also communicates with user or another microcontroller or any different kind of embedded system (fig. 1).

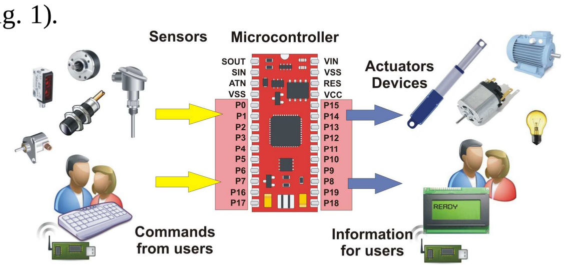

Figure 1 Role of the microcontroller in mechatronic systems

The product with embedded microcontroller behaves as intelligent systems. If it is necessary it could be as autonomous user less system. Behavior of such systems is subjected to user, which has possibility to affect to product processes. Products with embedded systems also could has another hidden additional functions as self-testing, self-monitoring, emergency function mode for crisis situations, self-repairing etc. These functions help to overcome various unexpected situations. Very often these products have the user guide function and help to users handling with this product. The paper is focused to data capturing via using the microcontroller [1-5].

2 TTL logic levels

Almost every computer works with binary coded signals. It means that everything is expressed with logical level one "1" and logical zeros "0". Digital electronics rely on binary logic to store, process, and transmit data or information. Binary Logic refers to one of two states – ON or OFF. This is commonly translated as a binary 1 or binary 0. A binary 1 is also referred to as a HIGH signal and a binary 0 is referred to as a LOW signal.

The simplest way is using of two state sensor, which has on output only logical zero or one. A majority of microcontroller systems we use rely on 5 V TTL Logic Levels. Transistor–transistor logic (TTL) is a class of digital circuits built from bipolar junction transistors (BJT) and resistors. It is called transistor–transistor logic because both the logic gating function (e.g., AND) and the amplifying function are performed by transistors (contrast with RTL and DTL).

For any logic family, there are a number of threshold voltage levels to know. The minimum output HIGH voltage is 2.5 V. Basically, this means that output voltage of the device driving HIGH will always be at least 2.5 V. The minimum input HIGH voltage is 2 V, or basically any voltage that is at least 2 V will be read in as a logic 1 (HIGH) to a TTL device. Likewise, the maximum output LOW voltage is 0.4 V. This means that a device trying to send out a logic 0 will always be below 0.4 V. The maximum input LOW voltage is 0.8 V. So, any input signal that is below 0.8 V will still be considered a logic 0 (LOW) when read into the device.

3 Switch (two state) sensors

Sensors convert measured variables into electrical signals (fig. 2). Nowadays, many sensors converts the signal into digital form at the point of measurement. Some sensors have simple two-state output (yes-no; "0" – "1") indicating the state of measured quantity, e.g. temperature detector, water level detector, smoke detector etc. Very frequently this type of sensors works as switch from electric viewpoint. In this case it is possible to connect these sensors directly to microcontroller input pin. This can be done by adding a pull-up resistor (to +5V), or a pull-down resistor (resistor to ground) on the input. A 20K resistor is a good value for a pull-up or pull-down resistor.

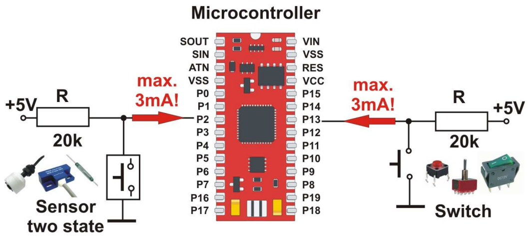

Figure 2 Switch sensors connected to microcontroller

4 Resistive sensors

Big group of sensors available on market are sensors with resistive output. The strategy for interfacing resistive sensors is generally to include them in a resistive voltage divider. This converts the resistance to a varying voltage. The voltage is then read with an Analog to Digital Converter (ADC). Very often microcontroller includes the ADC converter on specific pins. If there is no ADC pin on microcontroller, it is possible to use simple voltage divider adjusted to working between logical levels HIGH/LOW (fig. 3).

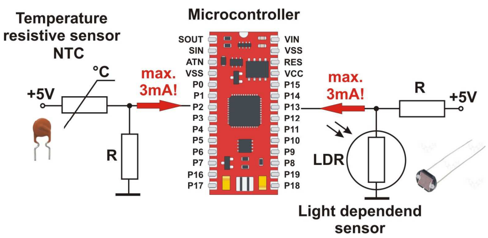

Figure 3 Resistive sensors connected to microcontroller

5 Sensors with pulse output

Microcontroller works with HIGH and LOW logical levels, so it is no problem to measure frequency modulated or pulse modulated signal from sensor like PWM (pulse width modulation) signal from accelerometer or encoder signal for measurement of rotation angle and velocity etc. Almost every microcontroller has built in counter/timer for reading and generating of pulse signal (fig. 4). PWM signal is very frequently used for controlling of DC motor speed.

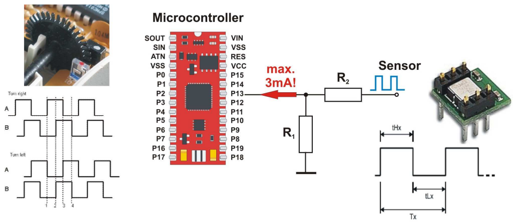

Figure 4 Pulse sensors connected to microcontroller

6 Controlling of power systems

Embedded system realized through the microcontroller includes signal processor. It means that it operates with low voltage and low currents, which are safely for the controller. The maximum current is limited to several milliampers. Direct connection most of actuators to pin of microcontroller causes the immediately damaging of pin al overall microcontroller.

This problem can be solved via using of high power part as transistor, thyristor, triac, relay etc. Inductive loads (DC and AC motors etc.) require big attention in selecting of power parts and circuits. Protection diode is very often used for this purpose (fig. 5).

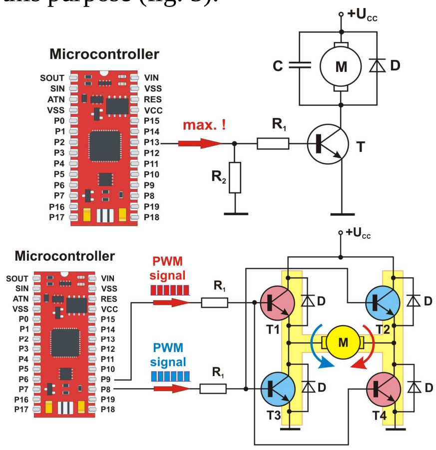

Figure 5 Microcontroller with power transistor and protection diode for inductive load and H-bridge for DC motor control

7 Controlling of RC servos

RC servo is positional servomechanism, which consists of DC motor, positional sensor and control electronic. There are rotational and also linear servos. Controlling of these servos is with conventional RC signal. It is pulse-width modulation signal and width of pulse constitutes the value of desired position of angular horn or linear shaft. Pulse width is in range from 1ms to 2 ms and delay between the pulses is in range from 10ms to 20ms (fig. 6). Pulse with width of 1ms means that rotation servo horn rotates to position -90° and pulse with width of 2ms means horn

Volume: 2 2017 Issue: 3 Pages: 7-12 ISSN 2453-7306

rotation to position +90° (fig. 6). Linear servo shaft is moving out to end position for pulse width of 1 ms and pulse with width of 2 ms causes the forward shifting of the linear servo shaft (fig. 6).

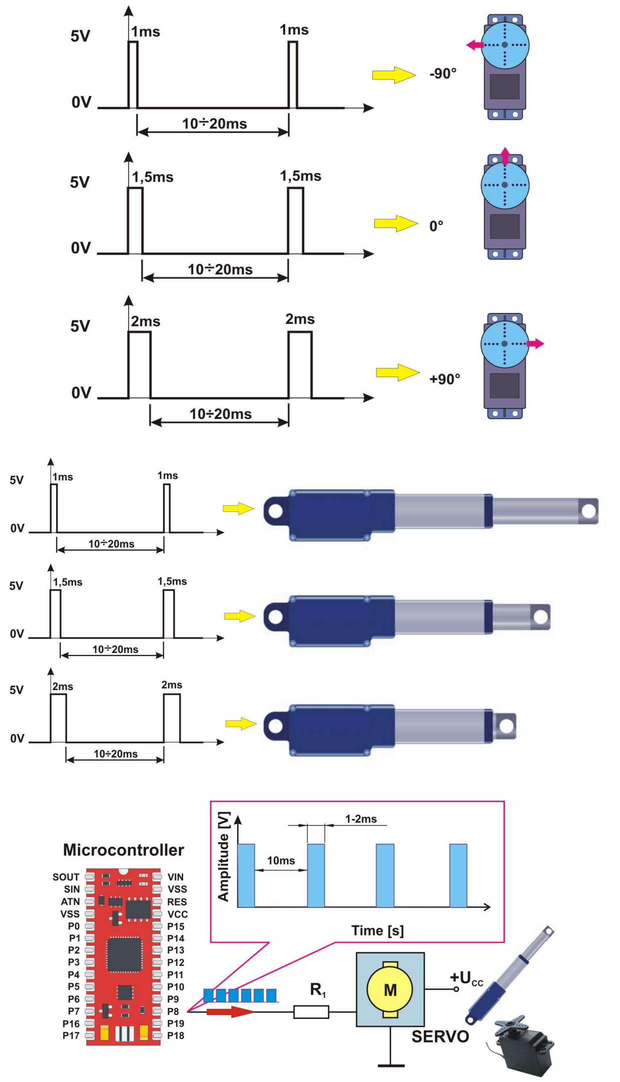

Figure 6 Principle of rotational servo and linear servo and connecting to microcontroller

8 Controlling of stepper motor

Stepping motor is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller), as long as the motor is carefully sized to the application in respect to torque and speed.

The stepper motor is known by its property to convert a train of input pulses (typically square wave pulses) into a precisely defined increment in the shaft position. Each pulse moves the shaft through a fixed angle.

There are two basic winding arrangements for the electromagnetic coils in a two phase stepper motor: bipolar and unipolar.

A unipolar stepper motor has one winding with center tap per phase. Each section (A, B, C, D) of windings is switched on for each direction of magnetic field. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple (e.g., a single transistor) for each winding (fig. 7).

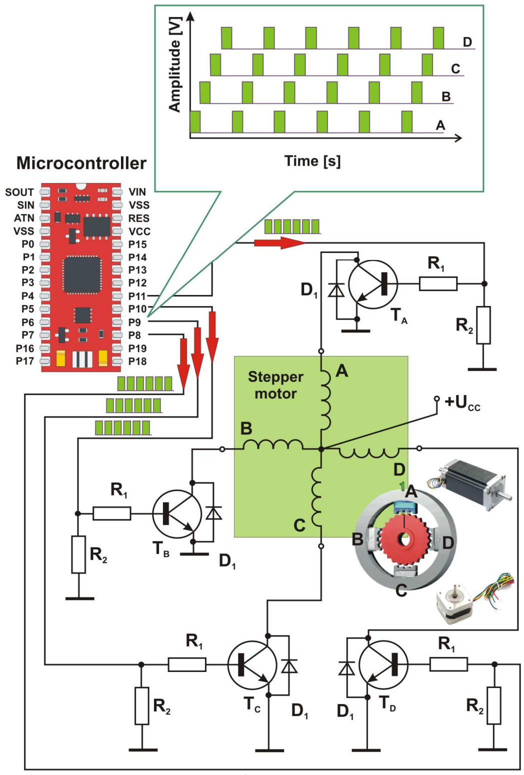

Figure 7 Controlling of the unipolar stepper motor

Abilities of microcontroller is limited to several input-output pins, limited amount of memory, limited instructions per second, limited simultaneously running processes etc. That is the reason of making the groups of microcontroller (fig. 8).

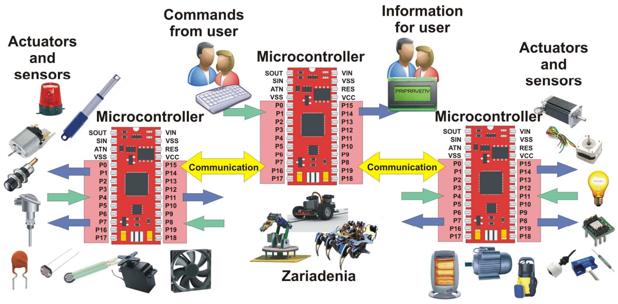

Figure 8 Multi-core embedded systems

All activities can be divided between these microcontrollers and system is faster than with one microcontroller. Also it is possible to make redundancy system with increased safety. It means that it is possible to

Acta Mechatronica - International Scientific Journal about Mechatronics
Volume: 2 2017 Issue: 3 Pages: 7-12 ISSN 2453-7306

develop product with self-testing, self-diagnostic, self-repairing, reconfigurable system, multitasking in real time and other activities which are too many for one microcontroller. This is reason why microcontrollers are grouped together in one product.

Main task is to compose the communication between microcontrollers for fast executing of processes. Safety communication is the first mainly in product, where human life is taking into account. Standard serial or parallel communication is used in multi-core embedded systems between microcontrollers. Serial communication is frequently used, but parallel communication takes many pins and wires and it is used only for some of LCD displays.

Many serial communication systems were originally designed to transfer data over relatively large distances through some sort of data cable. The term "serial" most often refers to the RS232 port on the back of the original IBM PC, often called as serial port.

Many variations of serial communications are used for microcontrollers: RS-232 (probably the most ubiquitous of all serial ports), RS-485, RS-422, UniversalSerialBus (USB), I2C (also IIC, InterIntegratedCircuit) Bus, Ethernet, PS2, FireWire IEEE 1394, CAN bus, SPI etc.

Holder if information is logical levels “0” and “1”, which can be realized for every type with different values of voltage. Microcontrollers frequently use TTL logic at all pins and some of the pins use also inverted logic RS-232 and I2C logic (fig. 9).

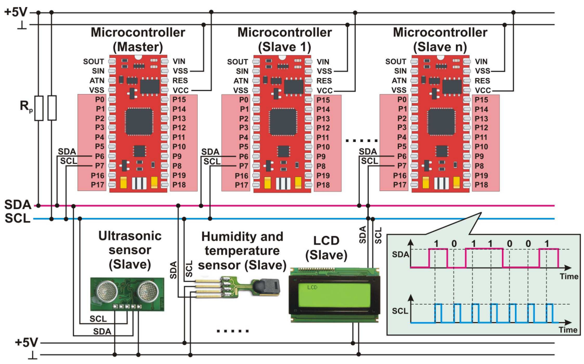

Figure 9 I2C communication in multi-core embedded systems

Other possibility is communication through the 1-Wire® bus also known as MicroLAN™ (fig. 10). It was defined by Dallas Semiconductor company as communication bus between electrical devices. It uses the same logical levels as TTL logic. The topology of this bus consists of only one data wire and common ground [6].

This bus allows the half-duplex both side communications. The specific property is that data wire can be used also as power supply for connected devices. This bus allows connecting up to 1500 devices into only one-wire bus [6].

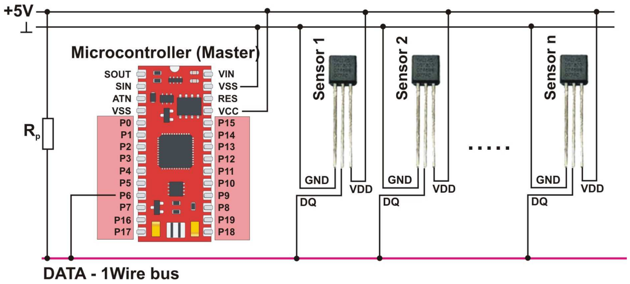

Figure 10 1Wire communication in multi-core embedded systems

9 Conclusion

More sophisticated didactic models are also used in educational process. Students design flowcharts for realization of specified functions and after that can write source code for programming of microcontroller.

Lift model as complex model (fig. 11) has been developed. Several master thesis and bachelor thesis have been defended on partial problems of this topic.

Line follower LINA 2010 (fig. 12) didactic model is developed for competition between students. Every student works on own algorithm and trains on this robot. After optimalization and completing of program students can compete. The main goal of competition is to follow line but also obstacle avoiding of brick is necessary. Line follower LINA 2010 also has to pass through the bridge and through the tunnel with door. Door is opened only when robot moves switching cube at minimum of 2 cm in any direction. The winner is who is the most quickly.

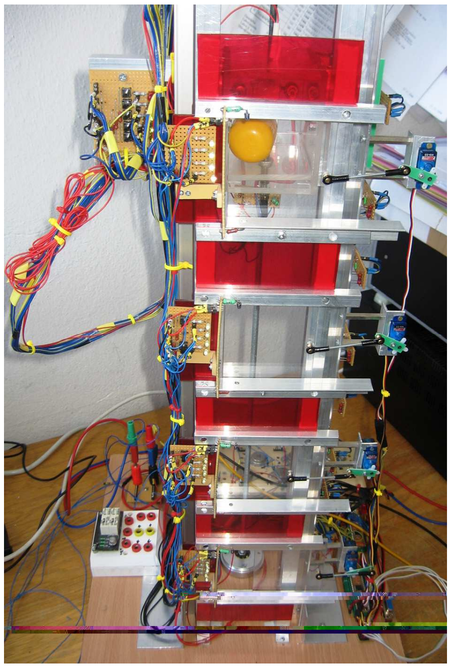

Figure 11 Didactic model of the lift

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Volume: 2 2017 Issue: 3 Pages: 7-12 ISSN 2453-7306

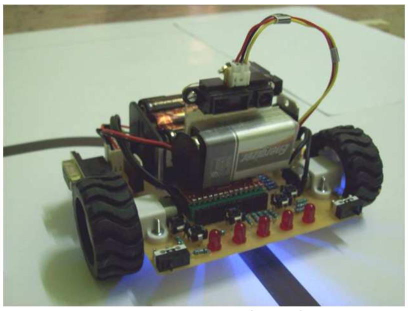

Figure 12 Didactic model of linefollower robot

Automotive industry is perfect place for using of embedded systems. The first electronic pieces were used to control engine functions and were referred to as engine control units (ECU). As electronic controls began to be used for more automotive applications, the acronym ECU took on the more general meaning of "electronic control unit", and then specific ECU's were developed. Now, ECU's are modular. Two types include engine control modules (ECM) or transmission control modules (TCM). A modern car may have up to 100 ECU's and a commercial vehicle up to 40. Car has many independent functions and automotive electronics or automotive embedded systems are distributed multi-core systems, and according to different domains in the automotive field, they can be classified into: engine electronics, transmission electronics, chassis electronics, active safety, driver assistance, passenger comfort, entertainment systems etc [1, 2].

Finally the automotive industry is still under the development and result of embedded systems including is the driver-less cars. [3-19].

Acknowledgement

This work was supported in part by the Grant Agency VEGA of the Slovak Ministry of Education Grant 1/0872/16 and 1/0389/18 and this contribution is also the result of the project implementation: Centre for research of control of technical, environmental and human risks for permanent development of production and products in mechanical engineering (ITMS:26220120060) supported by the Research & Development Operational Programme funded by the ERDF.

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Review process

Single-blind peer reviewed process by two reviewers.