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Original scientific paper

PERSONAL COMPUTER INTERFACE FOR TEMPERATURE MEASURING IN THE CUTTING PROCESS WITH TURNING

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The computer development aided research systems in the investigations of the characteristics of the surface layer forms conditions for decreasing of the measuring uncertainty. Especially important is the fact that the usage of open and self made measuring systems accomplishes the demands for a total control of the research process. This paper describes an original personal computer interface which is used in the newly built computer aided research system for temperature measuring in the machining with turning. This interface consists of optically-coupled linear isolation amplifier and an analog to digital (A/D) converter. It is designed for measuring of the thermo-voltage that is generated from the natural thermocouple workpiece-cutting tool. That is achieved by digitalizing the value of the thermo-voltage in data which is transmitted to the personal computer. The interface realization is a result of the research activity of the Faculty of Mechanical Engineering and the Faculty of Electrical Engineering in Skopje.

Key words: interface; amplifier; A/D converter; temperature; thermo-voltage

1. INTRODUCTION

The process of machining with turning is the most widely used in the machining processes by removing material. Usually, the constitution of the surface layer during this kind of machining is not guided properly as a result of not having enough knowledge for the physical phenomenon in the cutting zone. The demands for a high quality and productivity require machining process to come up with final products which have defined characteristics (known tribology characteristics, surface tonnage, determined quantity of oil which stays in the microfringe on the surface layer etc.) [K1]. The determination of the optimal characteristics for machining is the basic need for accomplishment of the specified demands. This may be done with mathematical modelling, but it is very difficult to take in consideration all the factors which affect the process, because of the process complexity. The more appropriate way for researching the physical phenomenon in the cutting zone is to use the experimental approach. The methods which are used during these researches have to fulfill certain demands. The high speed machining enabled by new metal cutting machines and new cutting materials requires usage of technique for fast conducting of the experiments, precise measuring of the values, fast and reliable acquisition of the experimental data, collecting large amount of measuring values in short intervals, fast data processing etc. This is essential for the required accuracy the observed experiment to be described. To achieve these criteria of the applied methods is possible only with usage of computer aided systems for identification of the phenomenon in our interest. Energetic transformations during machining in the cutting zone release a significant thermal energy. Unacceptable effects in the surface layer could occur during big contact temperatures, which are results of the generated thermal energy. That could decrease the positive tribology characteristics of the surface layer. The knowledge of this temperature is important with the fact that the temperature has direct influence on the value of the cutting forces and abrasive wear of the cutting tool. The conclusion is that during the investigation of this process, simultaneous identification of the temperature and the cutting forces is necessary. This provides correct conclusions about the process to be derived. The knowledge about the cutting process is very important from the construction and design of the cutting tool point of view, defining the process regime, predicting of the process errors, etc.

The need for design and construction of computer interfaces which are the link between the computer and the investigated process are arisen from all these statements. The interfaces for temperature measuring are usually divided in two parts. The carrier of the process signal might be of various medium. The first part is always designated for transformation of the process signal to electric analog signal which corresponds to the domain of the second part. The second part is always an A/D converter.

For example, the temperature measuring in the dry grinding process [J1] uses the infrared radiation as a basic index for the temperature value. In this case the first part of the interface is an amplifier and a converter of the infrared rays. The second part is the A/D converter.

Thermocouples which are inserted in the workpiece for temperature measuring are another similar example. Amplifier for the generated thermo-voltage is used in the first part of the interface. The second part is again the A/D converter [B1].

The presented designs of the interfaces depend on the chosen measurement method. All the methods have advantages and disadvantages. For measuring of the mean temperature in the machining with turning, the mostly used method is the method of natural thermocouple. A disadvantage of this method is the necessity for determination of the thermo-electric characteristics for each workpiece-cutting tool couple.

A personal computer interface which uses this method is created as a part of the newly built computer aided research stand for temperature measuring in the machining with turning on the Faculty of Mechanical Engineering in Skopje [N1].

2. DESCRIPTION OF THE INTERFACE FOR TEMPERATURE MEASURING IN THE MACHINING PROCESS WITH TURNING

Figure 1 demonstrates the principle block diagram of the newly designed personal computer interface for temperature measuring in the machining process with turning.

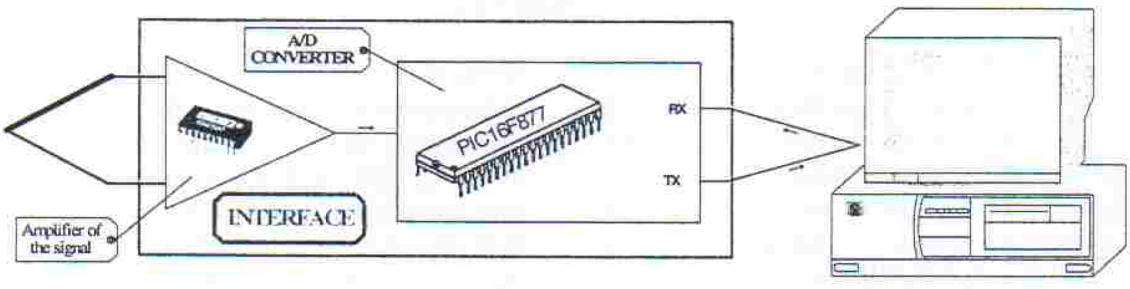


Fig. 1. Principle block diagram of the personal computer interface for temperature measuring in the machining process with turning

The interface consists of an amplifier of the signals and microcontroller with an A/D converter. The amplifier has three roles as a part of the interface. At first, to amplify the thermo-voltage that is generated by the natural thermocouple workpiece-cutting tool to the required level. That means that the signal after amplifying complies with the domain of the A/D converter. The second role of the amplifier is galvanic separation of the thermocouple electric circuit from the A/D converter and the personal computer. The role of this galvanic separation is protection from eventual current pulses that could damage this part of the measuring system. The third role is removing the influence of the electrical circuit consisting of the A/D converter and personal computer to the electrical circuit with the thermocouples. The basic component of the amplifier is the integrated circuit ISO 100 (Fig. 2) [D2].

Figure 3 shows the electrical connecting scheme for the amplifier and the thermocouple. The required amplifying is given with the ratio R_F/R_4. The analysis of the highest value of the thermo-voltage defines the amplifying, taking in consideration that the highest value which could be digitalized by the A/D converter is 5 Volts.

The integrated circuit ISO 100 consists of a primary and a secondary amplifier. Figure 3 also shows the system for power supply which generates two galvanic isolated symmetrical power supplies

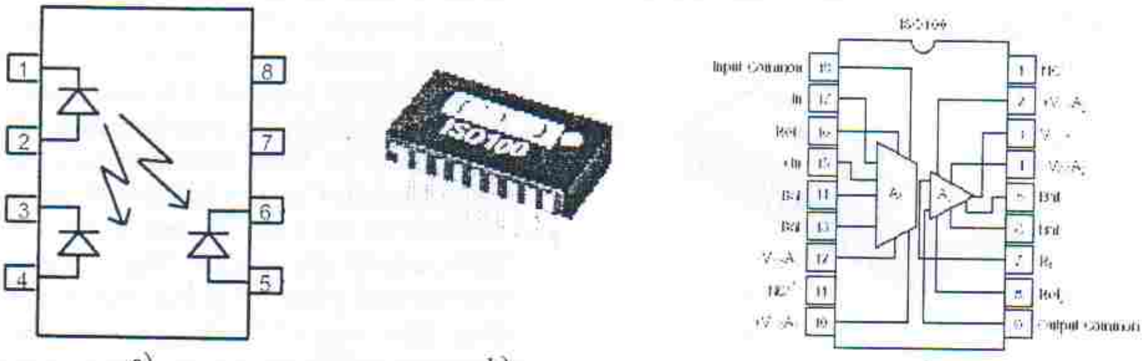


Fig. 2. Integrated circuit ISO 100
a) Functional diagram of the optically coupled isolation amplifier with photo-transmitting and photo-receiving diode; b) Integrated circuit ISO 100 shape; c) IC's pins

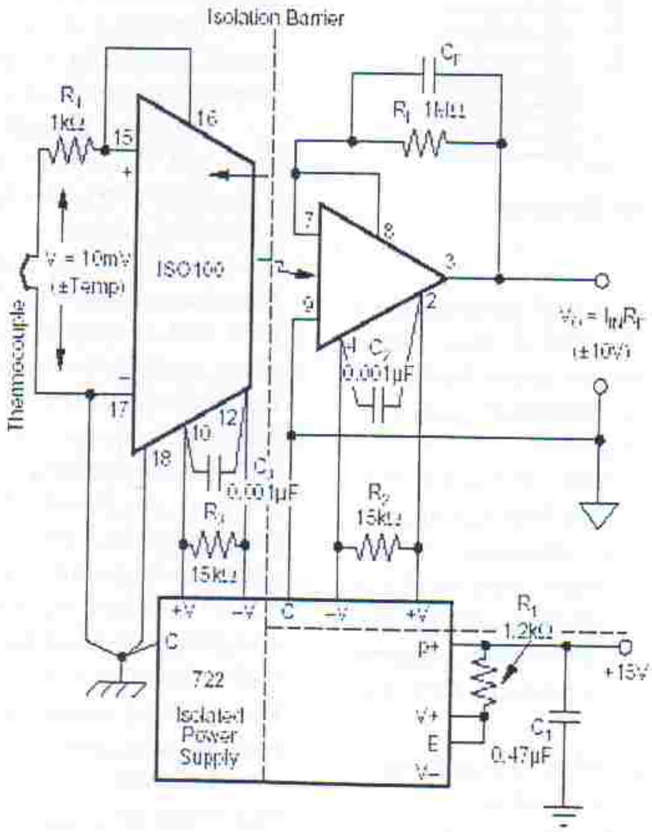


Fig. 3. Electrical scheme of the thermo-voltage amplifier

+V and –V as primary and secondary voltage supply for the amplifier. The optical leash divides the measuring system in two parts (electrical circuits). The first part, primary electrical circuit, consists of the natural thermocouple and the primary amplifier. The second part, secondary electrical circuit, consists of the secondary amplifier, the microcontroller with the A/D converter and the personal computer. The interface configuration could be more complex if the configuration has an independent A/D converter. Because of that, it was decided to use the Microchip's microcontroller PIC16F877 (Fig. 4) [W1].

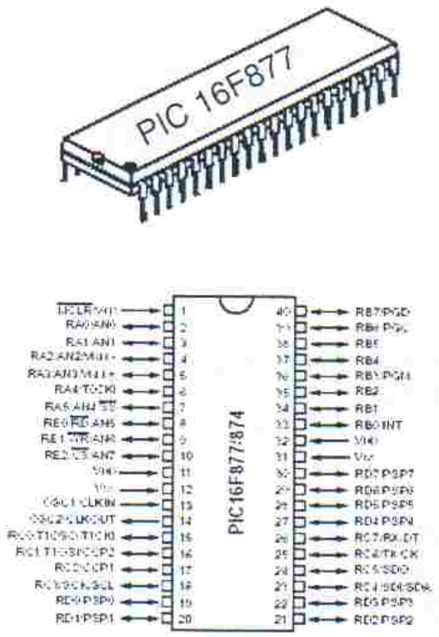


Fig. 4. Microcontroller PIC16F877

This microcontroller is a new generation of Microchip's microcontrollers and it has 10-bit build in A/D converter. It has an option for defining intern or extern voltage references and it is possible to make 8-channel digitalization [D1]. For 10-bit conversion it uses 12 clock-periods for conversion with time interval shorter then 1,6 μs, and that is 20 μs total time for the conversion. In real conditions this time is a little longer, because of the additional time necessary for selection of the channel, determining the end of conversion, adding control bits for the channel and working with low and high byte, etc.

The maximum frequency of the clock generator is 20 MHz. That means that the microcontroller provides 50000 conversions in second. The nature of our research imposes necessity of couple of samples per turn of the workpiece. For the maximum speed of 2000 turns per minute and 5 samples per turn, the system should make conversion and acquisition of 2000·5/60 samples. That is 167 samples, which is under the possibilities of the chosen system. The microcontroller consists of a build-in module for serial synchronous and asynchronous full duplex communication which is called USART (Universal Synchronous Asynchronous Receiver Transmitter). The communication speed is very easy adaptable. It was decided that 115200 bps is the most convenient communication speed, because it allows transfer of maximum data samples through the communication line. The communication protocol that was chosen is 8 data bits, start and stop bit, and frequency of the clock generator of 20 MHz. Taking in consideration that one temperature sample is 2·8 = 16 bits, using this protocol we can send, in "real time", 115200/16 = 7200 samples per second. That is 10 times faster than we need while using four channels at the same time. This way of sending data to the personal computer avoids temporary saving of the data in the microcontroller's system and provides the data flow to be in "real time". In the process of designing the A/D converter we were using the design and simulation software Proteus 6.3 Demo. This software has a library of analog and digital components including microcontrollers, virtual terminals, signal generators, measuring instruments, oscilloscopes, logic analyzers, generators etc. (Fig. 5).

The user friendly screen interface provides easy and fast design and simulation of the A/D converter's construction. The microcontroller in the simulation performs a function that is given with the microcontroller's software. The connection of the microcontroller and the certain program can be done with a simple browse option. The simulation offers options for debugging and tracing of eventual logic errors, execution of the microcontrollers program "step by step", preview of the values of the microcontroller's variables in "real time" etc. However, the Proteus 6.3 library does not have the component ISO 100. Time programmable voltage generator was used instead of the amplifier's circuit which couldn't be simulated. This substitution completely satisfied the testing. Specific and especially convenient role in the simulation and the testing is the option virtual terminal. This option manages simulation of the serial communication.

The role of the computer in the simulation was simulated using this option. Special attention has to be given to the option of connecting the simulation with the real RS232 interface of the computer.

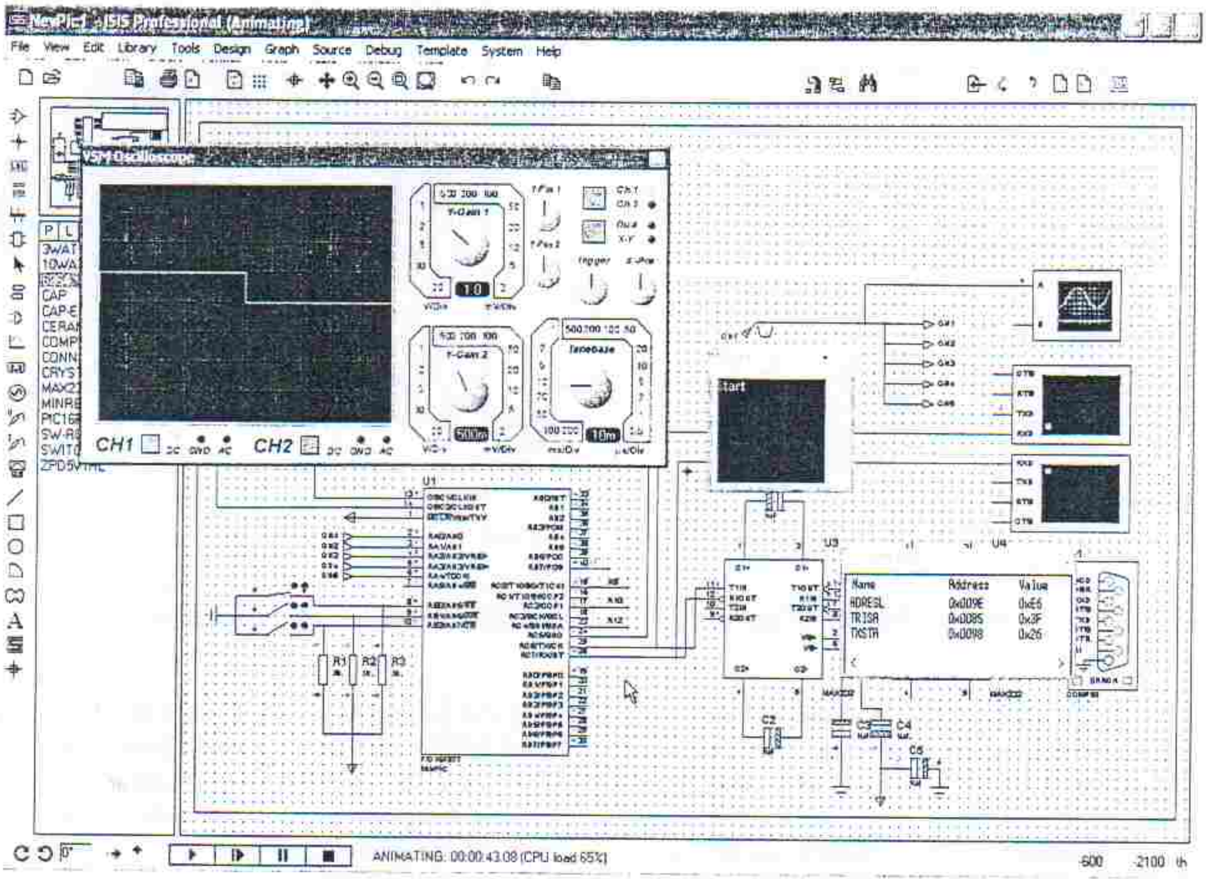


Fig. 5. Proteus 6.3 Demo window

This option gives the opportunity to test the real output/input using one personal computer for simulation of the A/D converter and another personal computer like a simulated interface user. The usage of two computers for the previous test could be avoided with application of a special software for software interconnection of two serial ports on the personal computer. For that purpose we were using the software package Virtual Serial Ports Driver XP4 (Fig. 6).

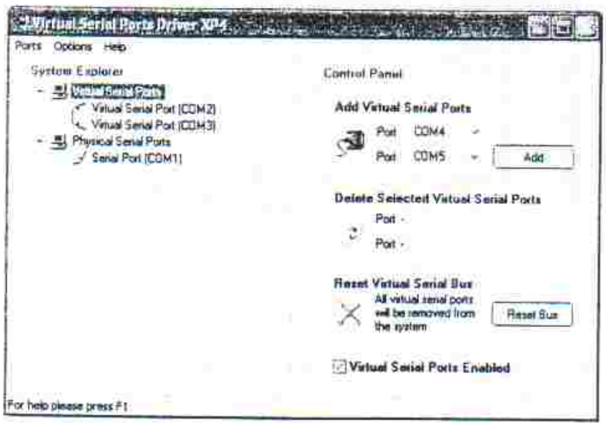


Fig. 6. Virtual Serial Ports Driver XP4 application window

The function of the microcontroller is directed by a program which can be written in different languages for microcontrollers. Example of an editor and C-compiler is given in Figure 7.

The compiled program in HEX-code was saved in the microcontroller's memory by the given programmer for microcontrollers (Fig. 8b) [W4]. The software IC-Prog 1.0, which supports the given programmer, was used for this procedure (Fig. 8a) [W3].

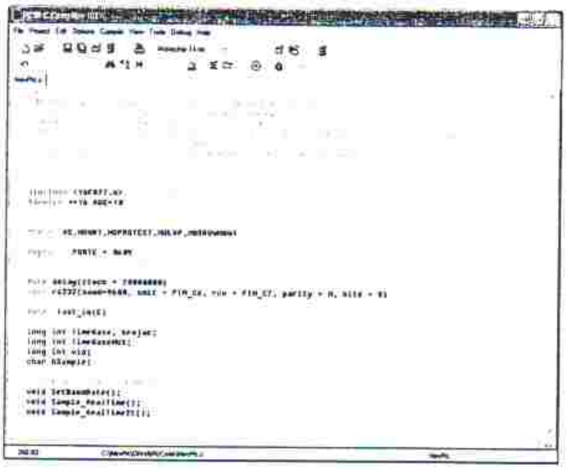
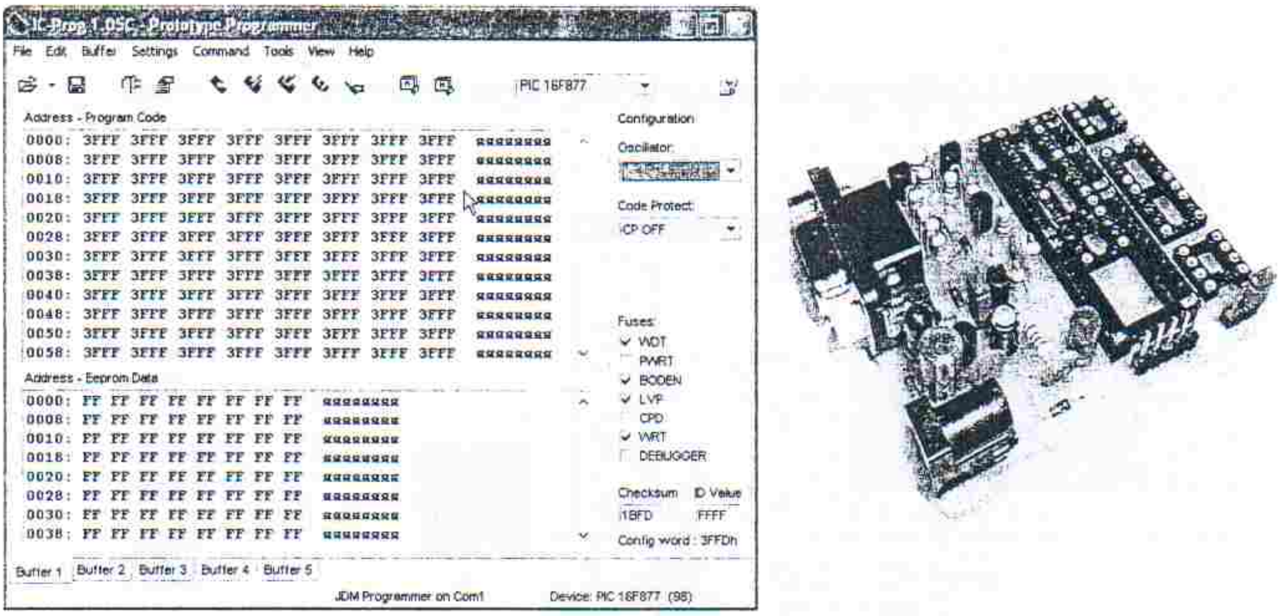


Fig. 7. Program editor and C-compiler for microcontrollers



a) b)

Fig. 8. a) Software for microcontrollers programming. b) Microcontrollers programmer

Figure 9 shows the electrical circuit of the A/D converter and its connection to the serial RS232 interface [W2]. The microcontroller's power supply is 5 Volts DC. Pins RC7 and RC6 from the microcontroller's USART are connected to the IC MAX232. The IC MAX232 is necessary for the microcontroller's voltage level adaptation to the RS232 interface's voltage level. For example, the logic "0" on the RS 232 interface with voltage levels from +3 to 12 Volts defers from the logic "0" on the microcontroller's USART which is voltage level of 0 Volts.

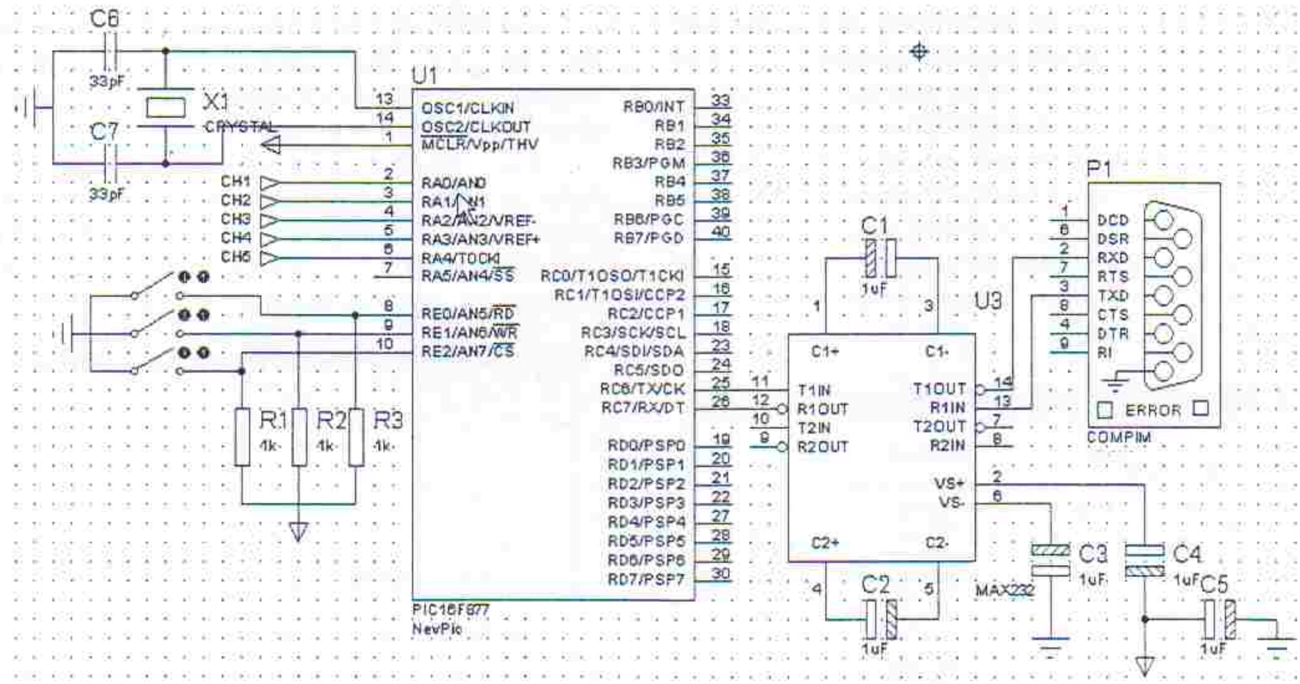


Fig. 9. Electric circuit-connection between the microcontroller PIC16F877 and RS232 interface

The three port E bits, RE0-RE2 are connected to the switches whose role is choosing low or high level to these bits. The specific combination adjusts the communication speed with the RS232 interface. The clock generator is completed by connecting a quartz crystal and capacitors on the pins OSC1 and OSC2. With P1 the mentioned option of simulation's software connection is marked to the real RS232 interface.

Figure 10 shows the realized described interface.

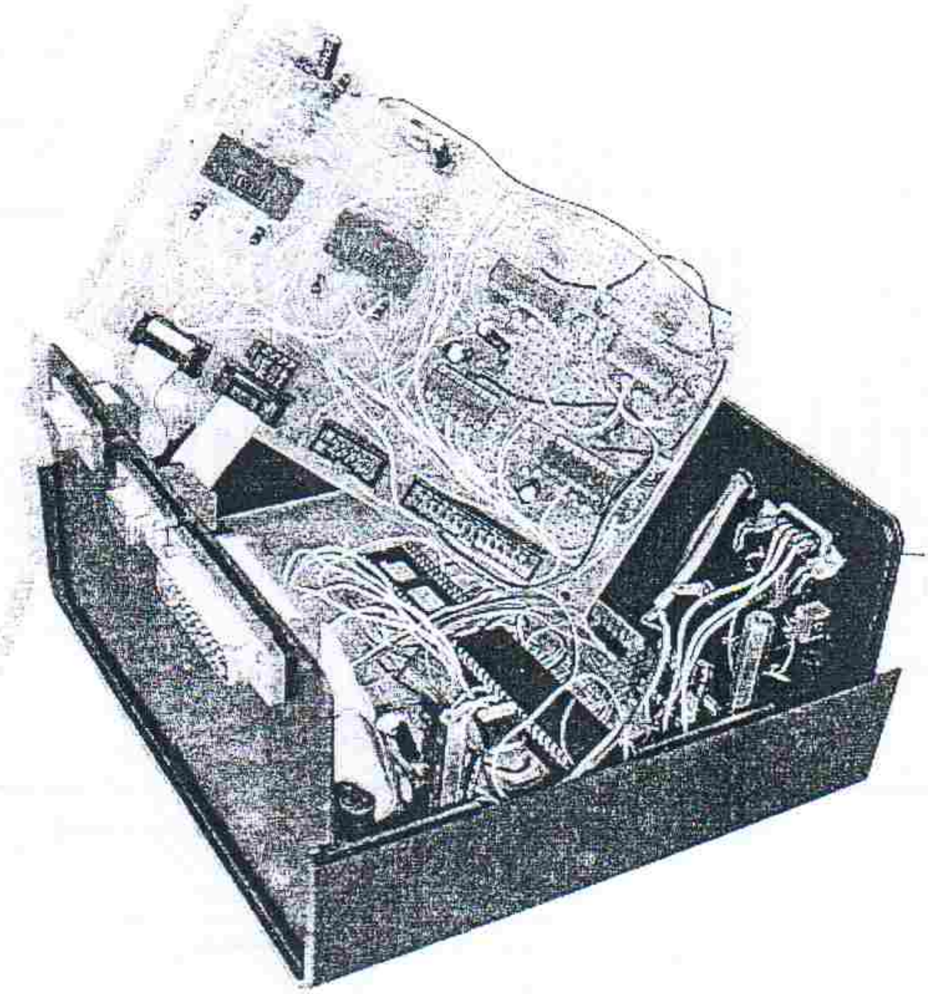


Fig. 10. Appearance of the realized interface for temperature measuring in the machining process with turning

3. TEST AND VERIFICATION OF THE INTERFACE FUNCTIONALITY

The test and verification of the interface functionality is done in three steps. At first, the test is done with signals from the signal generator which are passed trough the amplifier. A two channeled oscilloscope was used for measuring the input and output of the amplifier in the time domain. The conclusion is that the amplifier amplifies the input signal adequately to the defined amplifying coefficient. The nonlinearity of 0,01% corresponds to the data from the IC's datasheet and doesn't have significant influence to the signal dispersion.

The second step was testing the A/D converter with input periodical signals with different frequencies and wave forms (Fig. 11). The results of these test corresponded to the input signal.

The last step is testing the process that measures the generated thermo-voltage by the natural thermocouple. Figure 12 shows the signal shape that was obtained with measurements during the machining process with turning [N1]. The parameters of the machining were identical as the parameters of the experimental process in the ITMA, Wroclaw Polytechnic, Poland [K2]. The results can be called repeatable because the difference between them is only 1%. That confirms that the tested measuring system gives reliable results.

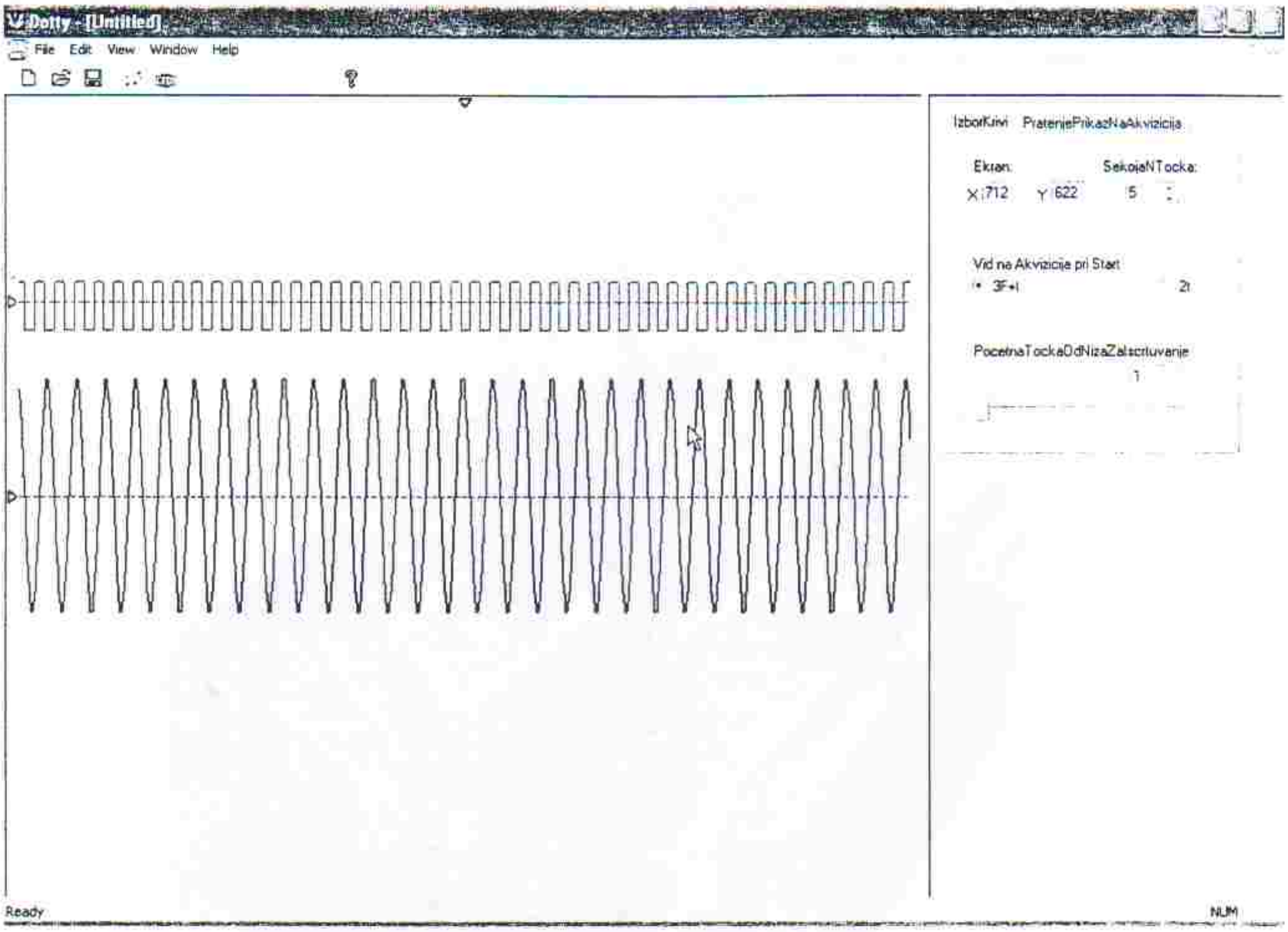


Fig. 11. Shape of the periodical signals during the A/D converter's testing

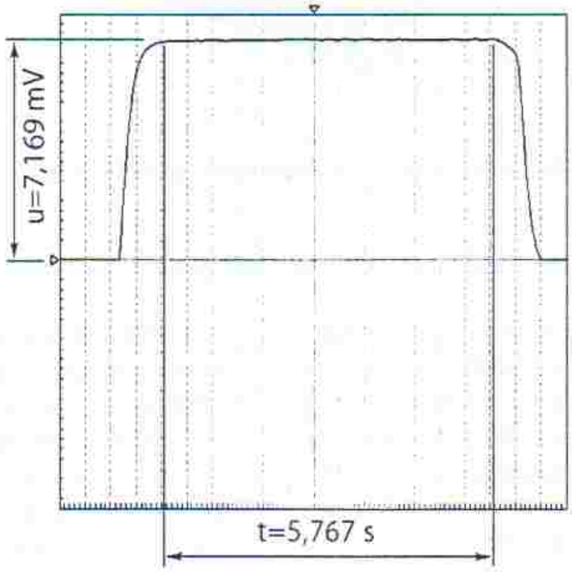


Fig. 12. Signal shape of the measured thermo-voltage

4. CONCLUSION

The results of the testing and the verification confirm the successful design of the computer interface. The usage of the integrated circuit ISO100 in order to amplify the signal was a good choice because it showed adequate characteristics for the specific requirements of the amplifier. The small nonlinearity given in the datasheet during the testing was confirmed and that makes the measuring system resistible to dispersion of the results. The possibility for definition of the amplifying coefficient with the use of the provided external components easily fits in the designed interface.

The deployment of the Microchip's microcontroller PIC16F877 like a "brain" of the interface simplified the configuration, because it integrates the main function: A/D conversion, and the communication interface. The microcontroller is easily programmable, as well as the use of the software for design of electrical circuits. The software package Proteus 6.3 Demo showed high professional characteristics while offering the needed possibilities.

The designed interface provides successful employment of computer aided research activities for temperature measuring in the process of machining with turning.

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WEB PAGES

[W1] http://www.microchip.com

[W2] http://www.arcelect.com/rs232.htm

[W3] http://www.ic-prog.com

[W4] http://www.yuelektro.cjb.net

DATA-SHEETS

[D1] Microchip, PIC16F87X

[D2] BURR-BROWN, ISO100

Резиме

ИНТЕРФЕЈС ЗА ПЕРСОНАЛЕН КОМПЈУТЕР ЗА МЕРЕЊЕ НА ТЕМПЕРАТУРАТА ВО ПРОЦЕСОТ НА РЕЖЕЊЕ ПРИ ОБРАБОТКА СО СТРУЖЕЊЕ

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Клучни зборови: интерфејс; засилувач; аналогно дигитален претворувач; температура; TEMS

Развојот на компјутерски потпомогнати истражувачки системи за истражување на карактеристиките на површинскиот слој конституиран во обработките со симнување на материјал во делот на експерименталните истражувања на физичките појави (отпори и температура во процесот на режење) создава

услови за намалување на интервалот на мерната неодреденост на добиените резултати од изведените истражувања. Особено е важен фактот што при употреба на отворени, по можност сопствени мерни системи, се исполнува условот за целосно владеење со истражувачкиот процес. Во овој труд е опишан оригинален интерфејс за персонален компјутер кој се користи во новосоздадениот компјутерски поддржан истражувачки систем за мерење на температура во процесот на режење при обработка со стружење. Интерфејсот е составен од оптокаплерски одвоен линеарен засилувач и аналогно дигитален претворувач. Неговата намена е мерење на термоелектромоторната сила (ТЕМС) генерирана од природниот термоелемент обработуван предмет – резачки алат, т.е. претворање на големината на ТЕМС во дигитални податоци кои се предаваат на персоналниот компјутер за понатамошно процесирање. Изведбата на интерфејсот е резултат на заедничката истражувачка активност на Машинскиот и Електротехничкиот факултет во Скопје.

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