Automatic measurement of time constant for temperature sensors

Artur Boguta, Marek Horyński

Lublin University of Technology, Faculty of Electrical Engineering and Computer Science,
Department of Computer and Electrical Engineering, Nadbystrzycka 38A, 20-618 Lublin, Poland,
phone: (+48 81) 53-84-301, fax: (+48 81) 525-46-01, e-mail: a.boguta@pollub.pl, m.horynski@pollub.pl

Received February 3.2013; accepted March 14.2013

Summary. The importance of temperature measurements is significant in many processes. The accuracy of said measurements is essential for the tasks to be performed by a product and for its compliance with requirements of applicable standards. The maintenance of determined temperature regime in individual production process phases is essential for the quality of obtained product. Apart from temperature measurement accuracy, the time of sensors response to its change is also extremely important. The response time of temperature regulators and controllers which may significantly affect the parameters of finished product, depends on the time of sensor response.

The measurements of time constants for temperature sensors are time consuming and proper equipment and knowledge are also required for this purpose. It is rather unproblematic in case of piece production scale but in case of mass production it is necessary to find a solution enabling the automation of time constant measuring process and ensuring measurements repeatability. The solution presented in this study will make it possible to automate the process and to reduce the time of measurement.

By means of proper software it will be possible to read the time constant from measuring system display.

Key words: time constant, temperature, temperature sensor.

THE STRUCTURE OF A SYSTEM FOR AUTOMATIC MEASUREMENT OF TIME CONSTANT OF PT 100 SENSORS

The system enabling the measurement of time constant for PT100 temperature sensors is illustrated in Fig. 1.

The measurement system consists of a hydraulic assembly ensuring the flow of fluid pre-heating the sensor being tested and changing its flow rate in individual phases of system operation. In the initial phase, the fluid circulates in the circuit consisting of water bath, fluid circulating tubes and check valve. In this operation phase, the fluid flows through the system elements and heats the whole circuit. The purpose of the check valve is to enable the fluid flow while an electro – valve is closed. The latter opens in the second phase and the fluid is supplied to the sensor under test causing a sudden change of sensor temperature. An algorithm recording the sensor temperature change at sudden temperature change is triggered in this operation phase. Temperature changes are recorded by means of one of analogue to digital (A/D) converters of microcontroller. Resistance changes are recorded 25 times/ second by means of the microcontroller [3, 4]. The recording time is equal to 25 s and is completely sufficient to ensure the stabilization of final temperature of the sensor under test. Internal memory of ATmega 64 microcontroller is used to record the values of resistance vs. time. The resistance is recorded as a WORD type variable in the table of variables [18, 19]. An original program has been created, compiled and entered into the microcontroller memory in order to make it possible to determine three time constants T0,50, T0,632, T0,90 [9,16]. The algorithm calculating the time constants performs the analysis of recorded numerical values displayed by A/D converter and determines three values i.e. 0,5, 0,632 and 0,9 for the recorded maximum value. The time elapsed between the system starting and occurrence of determined numerical values is determined on the basis of recorded measurement points (25 times /1s). Corresponding time constants measured by the system are specified on the basis of time elapsed until the recorded maximum value achieved 0,5, 0,632 and 0,9. After START pushbutton is depressed, the signal received from A/D converter is continuously analyzed by the microprocessor triggering the measurement procedure when a positive change of sensor temperature is detected.

Another task of applied microcontroller consists in the measurement of water bath temperature and measuring cylinder temperature. DS18B20 semiconductor sensors have been used for temperatures measurements. The temperatures measurement makes it possible to determine the temperature unit step and to check its conformity with applicable standard [1, 5, 12].

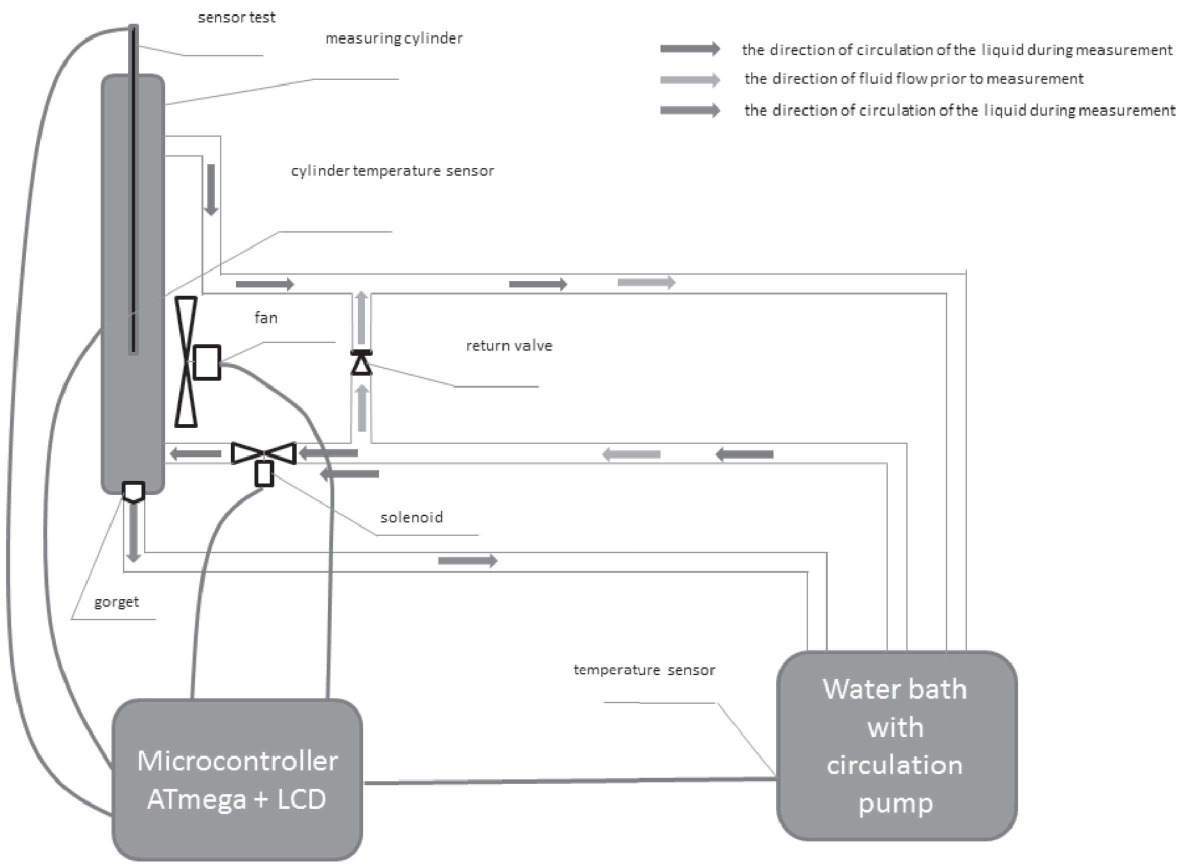

Fig. 1. The system for measurement of time constant for PT100 temperature sensors

After completed measurement, the measured values of time constant are displayed, electro – valve is closed, the fluid is discharged from measuring cylinder into water bath and the fan is turned on in order to cool the system before the next measurement.

The system has been equipped with a function protecting against an erroneous measurement (proper temperature difference, sensor not connected or damaged). In case of possibility of an erroneous measurement, the control system will make it impossible to turn on the system. Information about errors will be shown on LCD display and indicated by means of LED control lights [6, 7, 8].

Figure 2 illustrates the schematic diagram of an electronic system performing the following functions:

– temperatures control in course of system operation;
– control of electro-valve operation,
– control of cooling fan operation,
– measurement of PT100 sensor resistance,
– recording of resistance change vs. time,
– calculation of time constant value for the sensor under tests.

AVR Atmega 64 microcontroller performs the function of a system monitoring the operation of the whole measuring system. Said microcontroller supports an instrumentation amplifier based upon an integrated NE5532 operation amplifier[15]. The purpose of this amplifier is to match the Signac received from PT100 temperature sensor to adequate level required by A/D converter.

Completed measuring system has been tested in laboratory conditions. The tests were carried out on several PT 100 sensors and demonstrated that the time constants for PT 100 platinum temperature sensors are measured correctly by means of designed and completed system.

MEASUREMENTS

Completed system has been used for testing of temperature sensors basing upon PT100 measuring element. The measurements have been performed for more than ten sensors. The results of measurements for four (4) selected sensors have been presented in Table No 1.

Table 1. Time constant T0,5 for PT-100 sensors located in steel jackets with silicone filling

Item	Sensor No 1	Sensor No 2	Sensor No 3	Sensor No 4
	$T_{0,5}$ [s]	$T_{0,5}$ [s]	$T_{0,5}$ [s]	$T_{0,5}$ [s]
1	9,11	11,01	8,95	11,23
2	10,10	10,78	9,56	10,58
3	9,70	10,45	9,87	10,89
4	9,68	09,67	10,23	10,59
5	10,03	10,85	9,68	10,55
6	9,54	10,68	9,89	11,04
7	10,34	11,00	9,45	10,97
8	9,85	10,59	9,78	10,87
9	10,05	10,93	9,83	10,76
10	9,33	10,42	8,97	10,75
Average	9,77	10,63	9,62	10,82

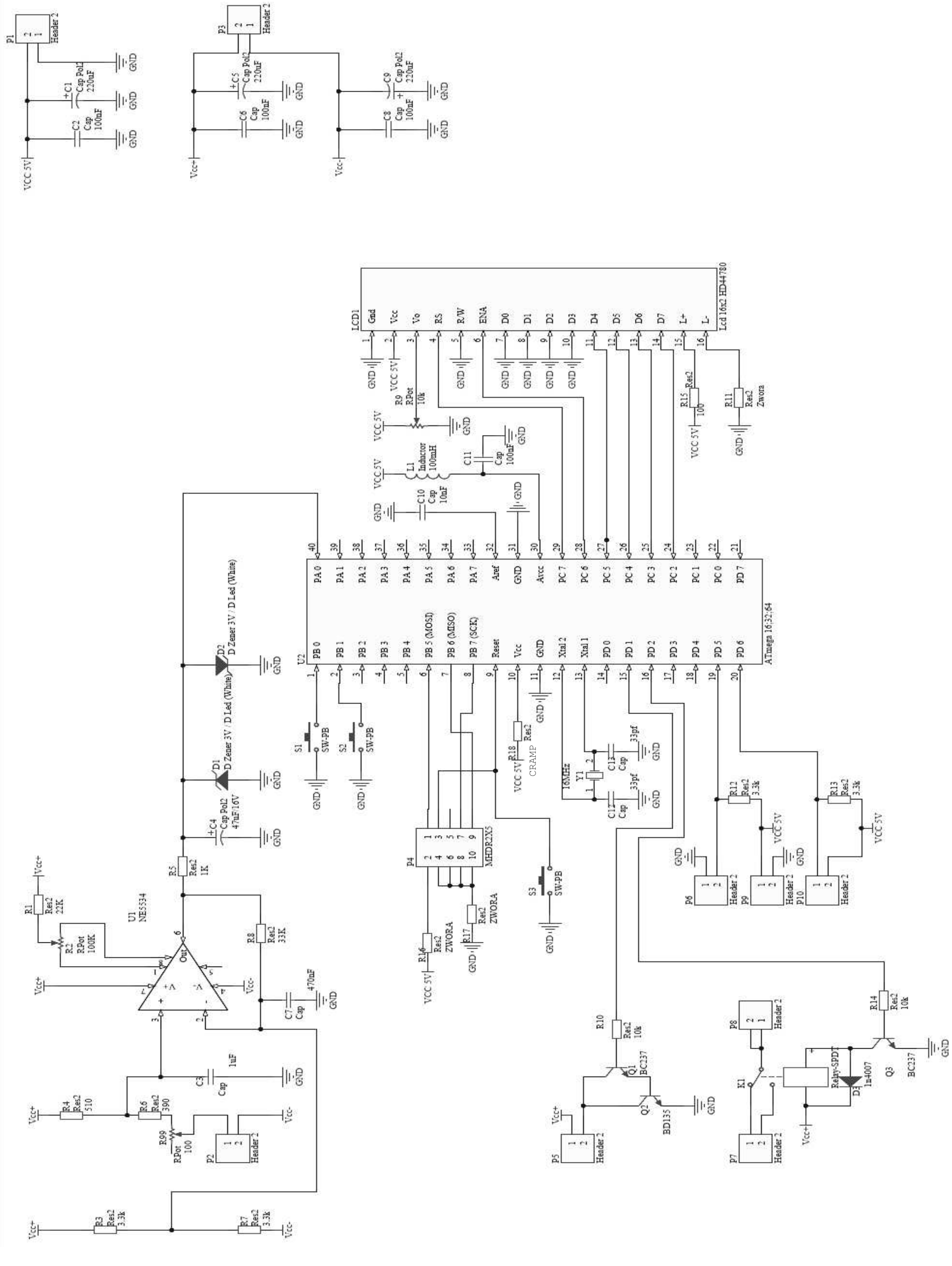

Fig. 2. Schematic diagram of a control and measuring system for determination of temperature sensors time constants

The measurements presented in Table No 1 correspond to measurements performed manually by means of a stop watch and digital multimeter. The results of measurements for individual sensors insignificantly differ from each other. The difference can be caused by an insignificant change of sensor resistance at the time of final temperature stabilization and by limited resolution of A/D converter in applied microcontroller.

CONCLUSIONS

The time constants for the transducers under tests are measured correctly by means of presented system designed for the determination of time constants for PT 100 transducers. Obtained results are conforming with the results obtained by means of manual method. A/D converter with higher resolution (10-bit version has been used in the system) can be used in order to increase the accuracy and repeatability of measurements.

There is a problem in the system being tested due to quick cooling of measuring cylinder. The cylinder consists of a copper tube characterized by good heat conductivity but its heat capacity is high. This significant heat capacity slows down the measuring cylinder process before the next measurement. The application of more efficient measuring cylinder process by means of a fan with increased efficiency or by means of fluid, could significantly reduce the time required to complete next measurements.

REFERENCES

1. **Baranowski R. 2005:** Mikrokontrolery AVR ATmega w praktyce. BTC Legionowo [AVR ATmega microcontrollers in practice].
2. **Brzoza-Woch R. 2010:** Mikroprocesory AT91AM9. BTC Legionowo [AT91AM9 microprocessors].
3. **Doliński J. 2009:** Mikrokontrolery AVR w praktyce. BTC Legionowo. [AVR Microcontrollers in practice].
4. **Doliński J. 2009:** Mikrokontrolery AVR, niezbędnik programisty. BTC Legionowo [AVR microcontrollers, programmer's toolbox].
5. **Górecki P. 2002:** Elektronika dla wszystkich. Mikroprocesorowa ośla łączka. AVT nr: 10, 11, 12 [Electronics for everyone. Górecki P.: An introduction to microprocessors].
6. **Górecki P. 2003:** Elektronika dla wszystkich. Mikroprocesorowa ośla łączka. AVT nr: 1, 2, 3, 4, 5, 6, 7, 10, 11, 12 [Electronics for everyone. Górecki P.: An introduction to microprocessors].
7. **Górecki P. 2004:** Elektronika dla wszystkich. Mikroprocesorowa ośla łączka. AVT nr: 1, 2, 3, 4, 6, 7, 8 [Electronics for everyone. Górecki P.: An introduction to microprocessors].
8. **Górecki P. 2005:** Elektronika dla wszystkich. Mikroprocesorowa ośla łączka. AVT nr: 5 [Electronics for everyone. Górecki P.: An introduction to microprocessors].
9. **Hagel A. 1975:** Miernictwo dynamiczne, WNT Warszawa [Dynamic measurement techniques].
10. **Horyński M. 2011:** Indor Climate Control in EIBSystem, Commission of Motorization and Power Industry in Agriculture TEKA XI/2011.
11. **Jabłoński T. 2010:** Mikrokontrolery PIC16F. BTC Legionowo [PIC16F microcontrollers].
12. **Kapica J. 2011:** Application of Microcontroller in Simulation of the Photovoltaic Generators. Commission of Motorization and Power Industry in Agriculture TEKA XI/2011.
13. **Michalski L, EckersdorfK. 1980:**Pomiary temperatury. WNT Warszawa [Temperature measurements].
14. **Michalski l., Eckersdorf K. 1971:** Pomiary temperatury, WNT Warszawa, Wyd. II [Temperature measurements].
15. **Pawluczuk A. 2006:** Sztuka programowania mikrokontrolerów AVR. BTC Warszawa [The art of AVR microcontrollers programming].
16. Polska Norma 1995- EN 60751+A2.
17. T**ietze U. Schenk CH. 1993:** Układy półprzewodnikowe. WNT Warszawa [Semi-conductor systems].
18. **Wiązania M. 2004:** Programowanie mikrokontrolerów w języku BASCOM. BTC Warszawa. [Microcontroller Programming in BASCOM].
19. **Wiązania M. 2008:** Bascom AVR w przykładach. BTC Legionowo. [AVR in examples].
20. **Wierzbicki S. 2006:** Diagnosing microprocessor-controlled systems, s. 182, TEKA 2006 -, Commission of Motorization and Power Industry in Agriculture.
21. **Wołgajew R. 2010:** Mikrokontrolery AVR dla poczatkujących. BTC Legionowo. [AVR Microcontrollers for beginners].