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Fluid temperature control using heat exchanger

Mircea Dulău[a,*], Melania Karoly[a], Tudor-Mircea Dulău[b]

[a] *"Petru Maior" University of Tîrgu Mureş, Nicolae Iorga Street, no.1, 540088, Tîrgu Mureş, Romania*
[b] *Technical University of Cluj Napoca, Memorandumului Street, no.28, 400114, Cluj Napoca, Romania*

Abstract

The paper presents an automated system used for the temperature control of the fluid, using a heat exchanger heated by an electrical resistance. The fluid is re-circulated through the exchanger by a d.c. electro-pump. The control algorithm is an on-off type with hysteresis one and it is implemented with a PIC microcontroller and a relay as its actuator. The most important data is presented on a seven segments display. In order to send the parameters of the process and the command states to the computer, the serial communication is used.

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Keywords: temperature control; heat exchanger; PIC microcontroller;

1. Introduction

Nowadays, taking into consideration the necessity of efficiency and improvement of the final product's quality, the precise control of the industrial processes' temperature is a mandatory operation. The fulfilling of these requirements implies the necessity of adequate strategies for monitoring and control.

In this paper, the authors propose a strategy of monitoring and control of the fluid's temperature, built around a PIC16F1827 microcontroller. This study refers to the design, implementation and testing of the control schematic. With adequate modifications, the schematic can be extended for the control of other parameters, such as flow, level, pressure etc.

* Corresponding author. Tel.: +40-265-233-212; fax: +40-265-233-212.
E-mail address: mircea.dulau@ing.upm.ro

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This field's literature presents the microcontrollers' using problem for the industrial applications and highlights similar studies and experiments. So, the fundamentals of the PIC microcontrollers, with hardware and software details, are very well presented in [1]. The elements of designing and implementation with microcontrollers and microprocessors, the set of instructions, the organizing and addressing of the memory, the interruption system etc. are developed in [2,3]. The basic schematic of the temperature control with associated mathematical models are developed in [4], the PID and the On-Off classical control algorithms with the tuning criteria are presented in [5]. Experiments of PID auto-tuning controllers, implemented on microcontrollers and used for the temperature control are developed in [6]. The paper [7] presents a P controller which is implemented with a PIC microcontroller for a thermal plant. The architecture of the temperature control system using the PIC18F4620 microcontroller, the MikroC programming software, the used C language and the PID control are presented in [8]. The paper [9] describes the functionality of a temperature controlling system using PIC18F45K22 microcontroller with LM35 sensor and MikroC compiler. An example of embedded system design for the temperature control, which uses the PIC16F876A, with different block diagrams and conditioning, are presented in [10]. In the paper [11] the microcontroller based water level sensing is investigated in order to manage the power consumption and the water overflow. The simulations of a PID controller on a 16-bit PIC24F series microcontroller for speed control of a DC motor in the presence of load torque is treated in [12]. In [13] the PIC16F628A microcontroller is used to generate 4 kHz PWM switching signal in order to design a low cost, low harmonics voltage source inverter. The paper [14] deals with a PIC microcontroller to monitor and record the value of temperature, humidity, soil moisture and sunlight of the natural environment. Accordingly with [15], the PIC microcontroller is use to show the change of the motor speed depending to the light and temperature. Also, for the design and implementation of the temperature control schematic presented in the paper, the recommendations from the [16, ..., 22] data sheets were considered.

2. The control schematic

The controlled parameter is the fluid's temperature crossing the interior path of a heat exchanger which is heated by an electrical resistance. The heat exchanger has rectangular shape, is made of aluminum and has two paths of 10mm diameter for the fluid circulation. In the middle of the heat exchanger, across its entire length, an electrical resistance (200W, 220V) is mounted. The fluid is forced to cross the heat exchanger using a submersible electro-pump (5W power, 200l/h maximum flow). The temperature transducer is a MCP 9700 Microchip integrated circuit and it is mounted on the heat exchanger. This sensor is a low power thermistor with linear characteristic and which generates a proportional voltage with the measured temperature. MCP 9700 does not need an additional circuit for the signal conditioning. The measurement domain is (-40 ÷ 125)°C, with an accuracy of ±4°C. At a (2.3÷5.5)V supply, the absorbed current is 6μA. The output of the sensor is calibrated to a slope of 10mV/^{o}C and has a DC offset of 500 mV, which allows the reading of the negative temperatures without a negative power supply.

According to the control schematic (Fig. 1), the PIC16F1827 microcontroller reads the temperature's value from the MCP 9700 sensor and makes the analog-numerical conversion of this value. The temperature is displayed on the MAX 7219 seven segment display. The microcontroller communicates with the computer through the serial interface. In order to control the electrical resistance and the electro-pump, the microcontroller generates command signals for a relay and for a transistor. The circuit uses a power supply which generates 5Vc.c. and 12Vc.c. voltages. In order to prevent the fluid's (water) boiling, the reference signal for the heat exchanger is established with 50^{o}C bigger than the reference for the fluid and it is limited to 100^{o}C.

The microcontroller has a precision internal oscillatory, configured to 16MHz, so a standard instruction is executed at 4MHz (F_{osc}/4). The ports of the microcontroller are used as follows:

- pins RA0 and RA1 are connected to the sensors: one for the water temperature measurement in the collecting vessel and another one for the water temperature measurement inside the heat exchanger;
- pins RA3, RA4, RA5 are connected to three buttons used for the control configurations: UP, DOWN and SET;
- pin RA7 is connected to the command of the electrical motor;
- pin RA2 is connected to the signal from the motor;
- pin RB0 is connected to the on-off command of the heating resistance;
- pins RB2, RB3, RB4 are used for the temperature display with SPI serial protocol;