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An effective temperature controller system using PID mechanism

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Abstract- *The variety of applications of PID controller has led to its increasing demand and wide acceptance in industry. One of its most interesting applications is Temperature Control. Nowadays control of room temperature is significantly required. In this paper, we attempt to model the Temperature Control System using PID controller which is applied to a room in order to monitor the desired temperature at all times. The room temperature is maintained at the desired value by controlling the air conditioner in such a way that it is turned off if the desired temperature exceeds the room temperature and it turns on if the desired temperature falls below the room temperature. The variation that takes place in the temperature is from 16°C to 27°C. This study includes real time temperature control using a PID controller implemented on a microcontroller.*

Keywords- PID control, embedded hardware, auto-tuning mechanism, micro-controllers

1. Introduction

PID Controllers are widely used in industrial applications because of their simplicity and robustness. There have 3 coefficients: proportional, derivative and integral coefficient. By tuning these coefficients to specific values, the desired functionality of the PID control can be achieved. The demand for accurate temperature control has always been prevalent in various domains such as homes, industries or office buildings where the temperature is maintained in order to maintain a comfortable environment for its inhabitants. One of the most important applications of PID control is to control temperature and maintain it to desired value. In order to meet this application one must employ certain control mechanisms. In the last decade extensive research has been made with respect to temperature control for different types of processes. In the paper the authors propose a PID thermal control system for a building with 2 floors (one room on one floor each). The heart of this system is ATMEGA 16 microcontroller. The study is conducted on auto tuning mechanisms as well as data acquisition and PID control mechanisms.

To demonstrate this effectively, a small model was constructed. This model represented a building having 2 air conditioned floors such that there is one room on each floor. Temperature sensors that authors used were Pt100 RTD's. For a better approximation of temperature 4 sensors were planted in each room. This implementation is low cost thus making it suitable for different applications with respect to control tactics for temperature control or to be suiting a specific plant design. The goal of this study is to analyze and develop an effective temperature control system that can be used anywhere be it a laboratory, hotel, hospitals etc. Plant implementation can easily be reused by users who are not expert in plant design. The plant architecture proposed in this paper permits to run air conditioning action while interacting with its components. The control architecture allows for the users to implement their knowledge of control engineering in an easy way due to process access by a friendly design. The designed application with ATMGA 16 is also useful in predictive control research for embedded controller. Moreover, in recent years, the requirements for the quality of control design in process increased due to the computing power high complexity.

The paper is organized as follows: the second part of the paper presents the cooling system design and implementation with ATMEGA 16. The next section deals with the data acquisition and model identification. In the third part of the paper a control system design based on PID controller was developed. Finally some conclusions are given.

2. Real World Application for Temperature Control Using ATMEGA 16(PID Action)

Large number of methodologies is dedicated to control the temperature in a realistic environment suitable to various needs. In order to obtain the optimum performance it would be beneficial to provide a temperature control structure by providing a safer cooling mechanism with better performances in terms of energy efficiency, flexibility and portability. Extensively research has been made on cooling control because of the necessity in practical applications. In this paper the idea focuses on a simple process that could be suitable to domestic application in order to illustrate different control design aspects. Moreover, the designed plant is a low cost application with components with ease of access. The plant consists of a cooling unit(Air conditioning mechanism), a RTD sensor and a microcontroller that are encapsulated in a small testing room, as is shown in the Fig. 1. The RTD sensors Pt 100 can detect temperatures in a wide range of -200°C to 850°C and are highly accurate.

Fig. 1 Practical Implementation of the cooling system.

To relieve the performance of the proposed cooling system it is necessary to increase the test room temperature with a relay mechanism which will turn on and off the air conditioner unit as and when required according to the temperature requirements. The temperature can be of two types:

1. Set Value: The value set by the user according to his demands.
2. Current Value: The current temperature of the room is displayed here.

The function of the cooling unit will be to decrease the air temperature of the test room. The microcontroller will send a signal to relay, which will command the solenoid valves in the cooling unit to turn off as shown in Fig. 2. In order to adjust the air temperature to the desired set point, a controller is needed. It is to be mentioned that the experiment starts from a fixed temperature in the testing room. The Pt 100 sensors keeps monitoring the temperature variations and sends values of detected temperature to microcontroller. One of the active elements of the system is the relay which will send tripping signals to the solenoid valves in the cooling unit whenever the threshold values are exceeded. Suppose the current room temperature is 27°C as measured by the temperature sensor and the user wants that the temperature should be maintained to a value say, 30°C. The temperature sensed by Pt 100 will be converted to a voltage level by the in-built ADC in ATMEGA 16 and this value will be manipulated by the PID action written in the controller. This value will then be sent to the relays which will sense that they have to turn off the cooling unit until the temperature increases and reaches to 30°C. This is how the process is being done.

The Pt100 RTD sensor is a useful transducer for the system. The sensor operates form -200ºC to 850ºC and in this application is used the 2 wire configuration considering basic temperature. With good accuracy and easy to calibrate it offers the actual temperature in degrees.

There are three boards employed in this paper:

1. Master Control Board: This board as shown in fig.2 controls the overall functioning of the system. This board contains the 40 pin PDIP ATMEGA 16 MICROCONTROLLER which contains the code for PID action as well as relay actuation written inside it. The 16 MHz operating frequency combined with 8 channels for the 10-bit Analog-to-Digital Module, 16K of Program Memory and 512 Bytes for Data EEPROM are a few of the features of ATMEGA 16. The microcontroller uses a 131 powerful instruction set which are mostly single clock cycle executions. The device permits enhanced USART Serial Communication and also admits 32 programmable I/O lines and 3 Timers/Counter. This board also has a LCD display mounted over whose sole purpose is to display the current and set temperatures of both the rooms.
2. Relay Control Board: This board houses relays which gets actuated when the microcontroller sends tripping signals as mentioned earlier. The relay used are Leone L90CSDS12V which are PCB power relays of rating: 1A, 5-24 VDC. The relays turn on-off the cooling unit as and when the microcontroller tells them to.
3. Button Board: This board contains the button circuit which are used to modify the set temperature. The user can increase or decrease the set temperature according to his whims.

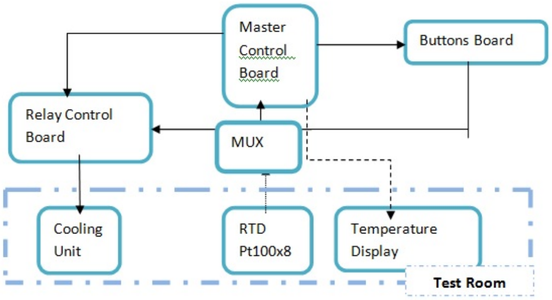

Fig. 2 - The process scheme

In the next section, the attention is focused on real time data acquisition, followed by the tuning methodology.

3. Auto Tuning and Control Design for the Cooling System

The perusal focuses on auto tuning methods, conjecture of control constants (K_p, K_d and K_i). The general intention of the process is to ensure a desired temperature in a closed loop safety operational methodology and for understanding the purpose of a cooling system. The aim of this study is to illustrate how to acquire real time data from the process, the auto tuning parameters and control system methods suitable for air temperature control. The system is linear, discrete-time and single input-single output. The input signal considered is the value of current room temperature read by Pt100 RTD sensor and the output is represented by the set room temperature value measured from the Pt100 RTD sensor which is set by user.

The system transfer functions are assumed to be functions in continuous time domain. Acquisition phase represents an important step in model identification of the dynamics of the plant that requires accuracy in sending input commands to the system and precise measurement of the output values. This involves a perfect timing between the command action and output signal. Data values, command signal and output offer a great possibility to create a complex or simplified model for the plant. Communication channels must be synchronized and safeguards must action to the potential external disturbances. The better model obtained the greater performance control action is performed. However, the distribution of the temperature depends on a lot of factors which influences the type and the parameters of the model..

The control command from the microcontroller is given using a AVR Studio 6, the code being written in Embedded C. In order to obtain a better approximation of current room temperature, 4 Pt100's are employed in each of the 2 rooms. 3 relays are used to actuate the solenoid valves at different times.

In order to acquire a representative data set the room temperature is varied from a temperature of 16ºC to 27ºC quick memory can record very accurate the A/D sent values. A number of samples in C degrees were recorded in this time.

The circuit with a set of readings was tested on virtual simulation Proteus 8 as shown below in Fig 3:

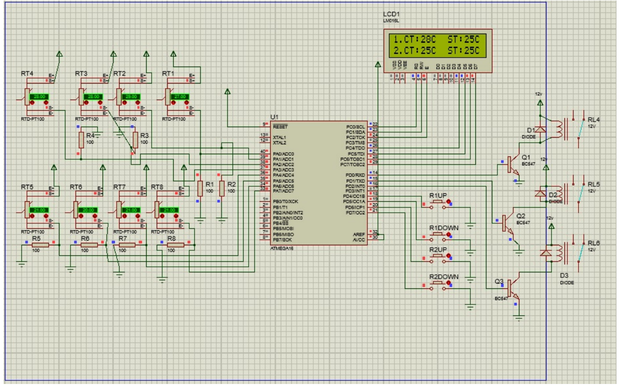

Fig. 3- Simulation of actual circuit on Proteus

4. The Control System Design for Temperature Control

In this perusal a parallel form of a proportional-integral-derivative controller was implemented. The form of the PID controller in the continuous time domain is expressed as:

$$U(t)= K_p.[1+\frac{1}{s}.T_i + s.T_d].E(t)$$

Where: E(t) is the signal error

U(t) is the control input to the process

K_p is the proportional gain

T_i is the integral time constant

T_d is the derivative time

For the discrete PID, the parameters were calculated with the following relations:

$$K_p^{(discrete)} = K_p$$

$$T_i^{(discrete)} = \frac{Kp \cdot Ts}{Ti}$$

$$T_d^{(discrete)} = \frac{Kp \cdot Td}{Ts}$$

The acquisition of the PID controller was based on several practical methods: Zeigler-Nichols method based on step response, Chien-Hrones-Reswick method and the Cohen-Coon Method. Using MATLAB Simulink Toolbox the parameters were obtained from the above mentioned methods the optimum and the best method is used for the PID execution. The tuning parameters based on Zeigler-Nichols method are: proportional gain $K_p = 6.746$, integral time $T_i = 61.313$, derivative time $T_d = 0$. The discrete time values for sampling period $T_s = 3$ seconds are: $K_p^{(discrete)} = 7.846$, $T_i^{(discrete)} = 0.802$. The above mentioned values were tested using the microcontroller set by the buttons circuit to set the desired temperature and cool down the temperature in the test room from the initial condition of 37˚ C to a new reference of 27˚ C. Using the Chien-Hrones-Reswick method results in the following parameters: Proportional Gain, $K_p = 5.429$, integral time $T_i = 55.136$, derivative time $T_d = 0$. The discrete time values using sampling period $T_s = 2$ seconds are:

$K_p^{(discrete)} = 5.829$, $T_i^{(discrete)} = 0.544$.

The continuous time parameters from Chien-Hrones-Reswick method were implemented considering as performances the zero overshoot and minimum time response.

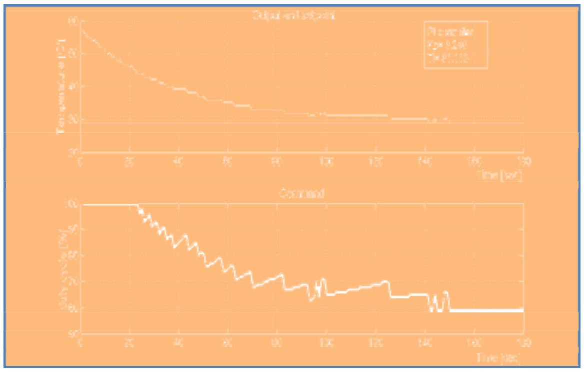

Fig.4- Ziegler-Nichols PI real time response

To achieve the optimum performances the tuning variables were slightly modified such as $K_p = 6$, and integral time $T_i = 50$, conclusion of the discrete time values $K_p^{(discrete)} = 6$, $T_i^{(discrete)} = 0.225$.

5. Conclusion and future work

In this paper we adequate the application for temperature control in an air conditioning ventilation system using the Atmega 16 Microcontroller was designed and developed. The controlling of the temperature is done by using PID technique. The Working components proposed in this project are Temperature sensor (Pt-100), Voltage regulator (7805), Relay switch (Leone L90CSDC12V), LCD display, Push Buttons and Bunch of 100 ohm resistors. The Structure of this project is exuberant which obliterate the excess knowledge for controlling the operations, hence it is easy to access a friendly design of this project. Some PID tuning methods have been examined and appropriate adjustments have been made to the parameters in order to obtain better performances.

The implemented PID controller on Atmega 16 Microcontroller can offer zero steady state error even if a load disturbance is introduced in the testing conditions. In this project we comprise the multiplexer for the RTD sensors data collection which obliterate the problem of voltage sharing. In the cases where the working model response is slow, it may be possible to decrease the processor speed and save power. Future work comprise research of some advanced control strategies and the implementation on this low cost plant, latter we use the control mechanisms which is based on convectional thermostats which is power unversed hence it may reflect poor control actions in terms of small sampling rate.

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