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PC BASED PID TEMPERATURE CONTROLLER

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ABSTRACT: *A simple and versatile PC based Programmable temperature controller employing an add-on ADC/DAC card has been implemented and tested successfully. The use of a computer improved the accuracy of the system and makes it user friendly with on line tuning. The major difference in the approach between any conventional method and the present one is the replacement of elaborate control circuitry of the former by any easily programmable algorithm with control equations. This gives one flexibility in selecting and programming the control functions such as set point control and controlled heating/cooling through software. The paper deals with the design and constructional features of a computer based temperature controller. In this experimental setup we have used a nichrome wire as the heater coil, which is wound over a copper block whose temperature is to be measured and controlled. The system is to be integrated with a temperature dependent ac conductivity measurement set up. The system achieves an accuracy of* $\pm 1^0C$.

KEYWORDS: Programmable control, PID control, Signal detection, Temperature controller

INTRODUCTION

The most widely measured phenomena in the process control environment is temperature. Common elements such as Resistance temperature detectors (RTD), thermistors, thermocouples or diodes are used to sense absolute temperatures as well as changes in temperatures. The platinum RTD temperature-sensing element is the most accurate and stable over time and temperature. RTD element technologies are constantly improving, further enhancing the quality of the temperature measurement. Typically, a data acquisition system conditions the analog signal from the RTD sensor, making the analog translation of the temperature usable in the digital domain.A temperature controller accepts an input from a temperature sensor and has an output that is connected to a control element such as a heater or fan. To accurately control process temperature without extensive operator involvement a temperature control system relies upon a controller. It compares the actual temperature to the desired control temperature or set point and provides an output to a control element. The controller is one part of the entire control system and the whole system should be analysed in selecting the proper controller. The following particulars should be considered when selecting a controller

(a) Type of input sensor and temperature range.
(b) Type of output required
(c) Control algorithm needed
(d) Type of output

In the present paper we report the design and implementation of a PC based temperature controller using four wire lead techniques that reduces the error caused due to lead wire resistance.

I. INSTRUMENTATION

A. *Principle of working*

A platinum RTD sensor is used as the temperature sensor whose output is appropriately modified using a signal conditioner. A constant current source is used to excite the RTD. The output of the signal conditioner which is a analog voltage is digitized using an ADC in the Digital I/O card and is read by the computer. This voltage is read in the PID program and converted to corresponding temperature. The system compares this temperature with the set point temperature and computes the error. This error is fed to the PID algorithm [1].
The controller algorithm is stated below:
If E is the present error,

Proportional output, $P_{out} = K_p \times E$ (1)

where K_p is the proportional constant

According to the principles of PID control, the proportional gain should multiply all the three terms [1].

$$E_{sum} = E_{sum} + E,$$

where E_{sum} is the sum of previous error

Integral output, $I_{out} = K_p x K_i x E_{sum}$ (2)

where K_i is the Integral constant

Now, for derivative output, $E_1 = E - E_0$

$E_0 = E$

E_0 is the previous error

Derivative output, $D_{out} = K_p x K_d x E_1$ (3)

K_d is the derivative constant

Then, PID output is given by

$$PID_{out} = P_{out} + I_{out} + D_{out} \quad (4)$$

PID controller combines proportional control with integral and derivative control, which helps the unit automatically compensate for change in the system. The proportional, integral and derivative terms must be individually adjusted or tuned to a particular system using trial and error. It provides the most accurate and stable control and is best used in system, which have a relatively small mass, those which reset quickly to changes in the energy added to the process. This type of control is recommended in system where the load changes often and the controller is expected to compensate automatically due to frequent change in set point, the amount of energy available or the mass to be controlled.At any point of time the current value of PID output depends on the present and previous errors, the time interval and the constants K_p , K_i and K_d . The output of the controller is a digital value, which is fed to the DAC of the Digital I/O card. The DAC converts it to a corresponding voltage and feds it to the heater circuit that will control the current passing through the heater and hence the temperature.

Hardware and software details

The block diagram for the entire set up is shown in Fig.1. The temperature sensor used is a platinum-100 (Pt-100) RTD. RTDs operate on the principle of changes in the electrical resistance of pure metals and are characterized by a linear positive change in resistance with temperature. Typical elements used for RTDs include nickel (Ni) and copper (Cu), but platinum (Pt) is by far the most common because of its wide temperature range, excellent stability, good accuracy, and repeatability. They exhibit the most linear signal with respect to temperature of any electronic temperature sensor. RTDs are also relatively immune to electrical noise and therefore well suited for temperature measurement in industrial environments, especially around motors, generators and other high voltage equipment. Since RTD is a passive measurement device it require an excitation current. To avoid self-heating, which is caused by current flowing through the RTD, the excitation current should be as minimum as possible.

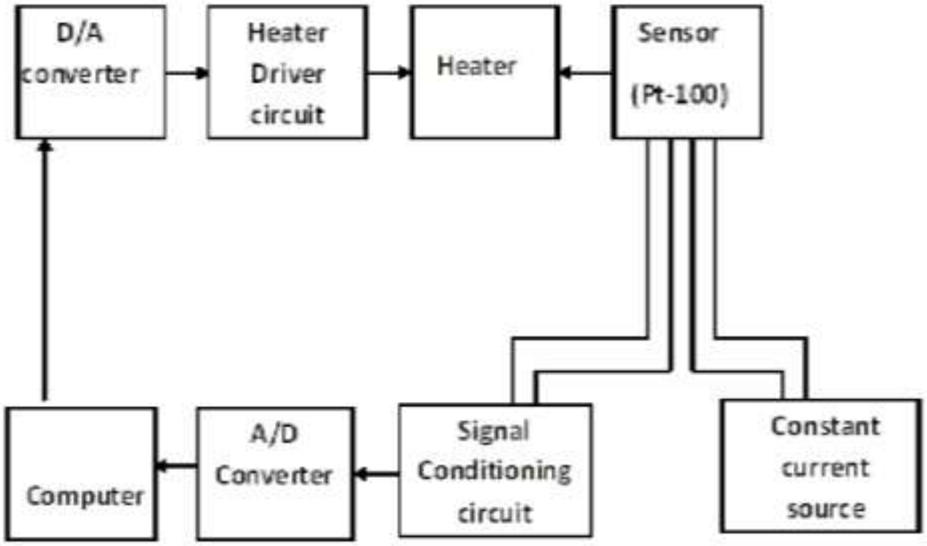

Fig. 1. Block Diagram of PC Based Temperature Controller

The following relation gives the relation between temperature and resistance of the platinum wire

$$R_t = R_0\left(1 + AT + BT^2 + ...\right) \tag{5}$$

Neglecting second and higher order terms, the equation becomes

$$R_t = R_0(1 + AT) \tag{6}$$

The signal conditioning circuit is employed for converting RTD resistance to a suitable voltage. It is shown in Fig: 2. A constant current source [2] of 1mA is designed using operational amplifiers to excite the RTD. A four-wire measurement technique is used for reducing the lead wire resistance errors. So one set of lead wire is used for current carrying purpose and another set for sensing application. A constant current source is designed using two operational amplifiers and a voltage reference. This is accomplished by applying a precision voltage reference to R_{14} of the circuit. Since R_{14} is equal to R_{13} and the non-inverting input to U_2 is high-impedance, the voltage drop across these two resistors is equal. The voltage is gained by $(1 + R_1/R_5)$ to the output of the amplifier and the top of reference resistor, Rref. The voltage at the output of U_2 is equal to:

$$V_{out\,U_2} = (1 + R_1/R_5) \times \left(V_{ref} - V_{R_{14}}\right) \tag{7a}$$

Since $R_1 = R_5$,

$$V_{out\,U_2} = 2 \times \left(V_{ref} - V_{R_{14}}\right) \tag{7b}$$

The voltage at the output of U_5

$$V_{out\,U_5} = V_{ref} - V_{R_{14}} - V_{R_{13}} \tag{8}$$

This same voltage appears at the inverting input of U_5 and across to the non-inverting input of U_5. Solving these equations, the voltage drop across the reference resistor, R_{ref} is equal to:

$$V_{R\,ref} = V_{out\,U_2} - V_{out\,U_5} \tag{9a}$$

$$V_{R\,ref} = 2 \times \left(V_{ref} - V_{R_{14}}\right) - \left(V_{ref} - V_{R_{14}} - V_{R_{13}}\right) \tag{9b}$$

$$V_{R\,ref} = V_{ref} \tag{9c}$$

The current through R_{ref} is equal to:

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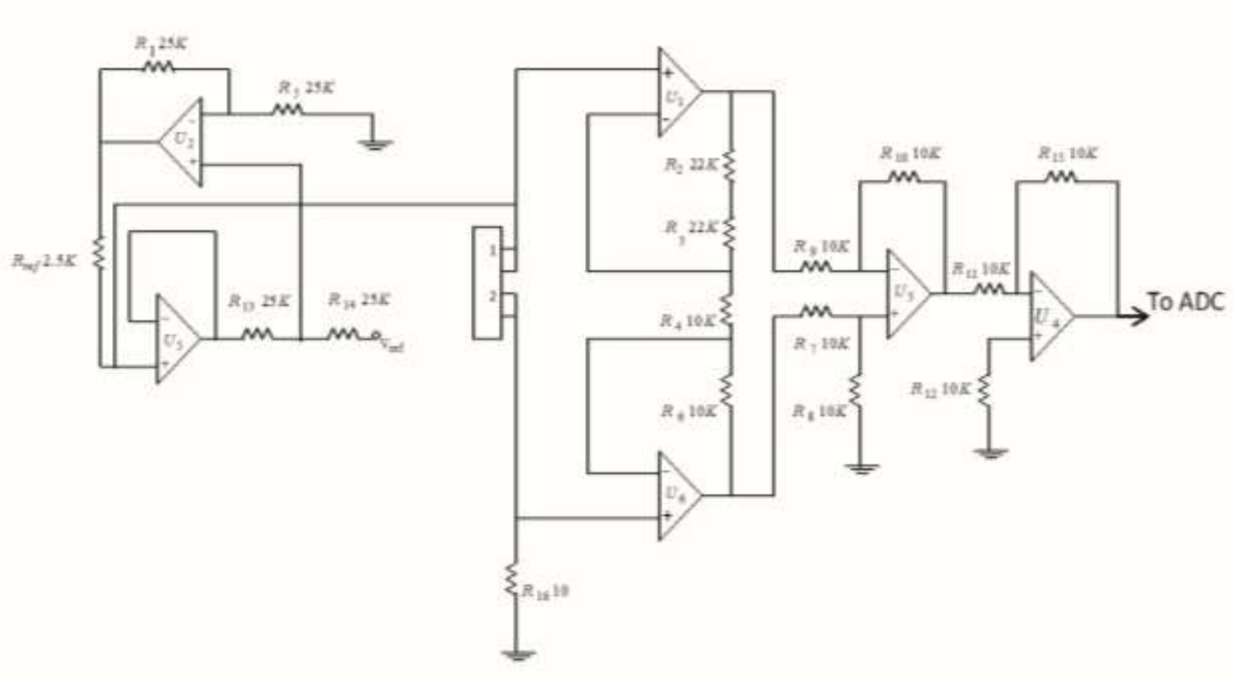

$$I_{rtd} = V_{ref} / R_{ref} \tag{10}$$

When this current passes through the temperature sensor Pt-100, it produces differential voltage given by the relation

$$\Delta V = 1mA \times \text{Resistance of Pt}-100 \tag{11}$$

This voltage drop across the RTD element is sensed and amplified in the 0-10Vrange using an instrumentation amplifier designed using operational amplifiers to increase the sensitivity of the system.Here we are using ALS-PC-02, ADC/DAC Digital I/O card designed to use with XT/AT compatible I/O channel bus. This card provides 12-bit A/D and D/A conversion facility. The ADC has a conversion speed of 25µsecs. The DAC has a fast settling time of less than 3µsecs. Both the ADC and DAC are used in the unipolar mode.

The voltage generated at the output of the DAC is fed to the heater circuit [3]. The heater circuit is shown in Fig: 3

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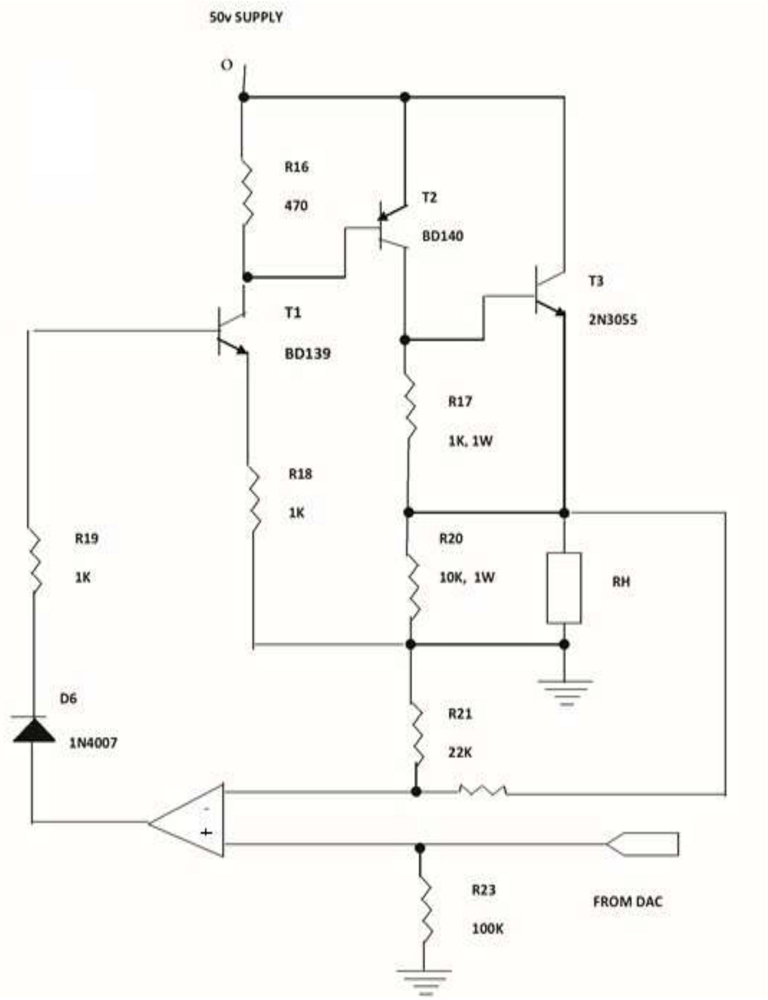

Fig. 3. Heater Circuit

The heater circuit is composed of operational amplifier and discrete transistor booster circuit including T_1 toT_3. The voltage swing capability is increased from 10 to 50V by transistorsT_1, T2 and transistorT_3 enhances the current capability. RH is the heater whose temperature is to be controlled. The power amplifier can deliver 100W to the load; T3 has adequate heat sink. Heavy dc feedback employed in this circuit ensures high stability and prevents ripple in the +50vsupply from appearing across the heater.

The necessary software is designed to realize the following.

(a) To acquire temperature of copper block as voltage through the ADC of the Digital I/O card.

(b) To convert the voltage read to corresponding temperature.

(c) To compute the error.

(d) To solve the PID equations.

(e) To generate a voltage from the DAC.

(f) To display the measured and set point temperature, error, PID output etc.

WORKING OF THE SYSTEM

The temperature of the copper block whose temperature is to be measured is sensed using Pt-100, RTD. The voltage drop across the RTD is sensed and amplified in the 0-10V range using the signal conditioning circuit constructed with operational amplifiers. This voltage is fed to the ADC input of the ADC/DAC card. The voltage is read by the PC using the PID program. In the PID program this voltage is converted to corresponding temperature and is compared with the set point. The error is calculated. Depending upon the error, the program outputs a voltage to the input of the DAC .The voltage from the output of the DAC is fed to the heater circuit. This voltage controls the current passing through the heater and hence the temperature.

The software is written in C language. The software makes the system user friendly. It provides online tuning of the PID parameters. The temperature data can be stored in the file name given by the user at the beginning of the program or at any time.

RESULTS AND DISCUSSIONS

Fig. 4(a) and (b) shows the temperature response of the PID controller.

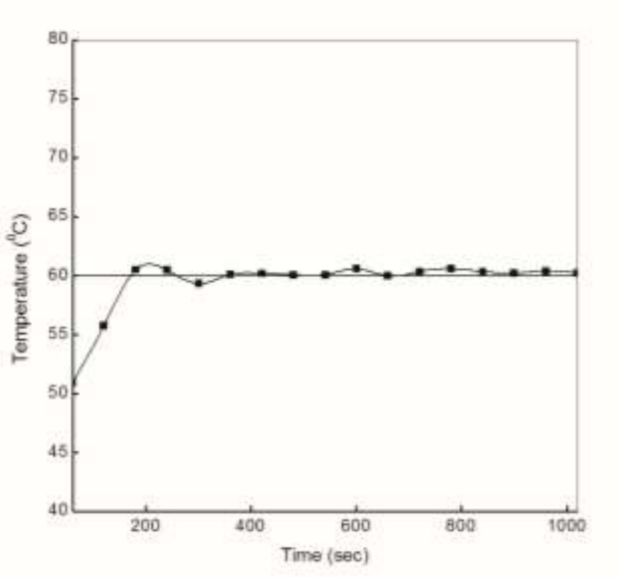

Fig. 4(a)

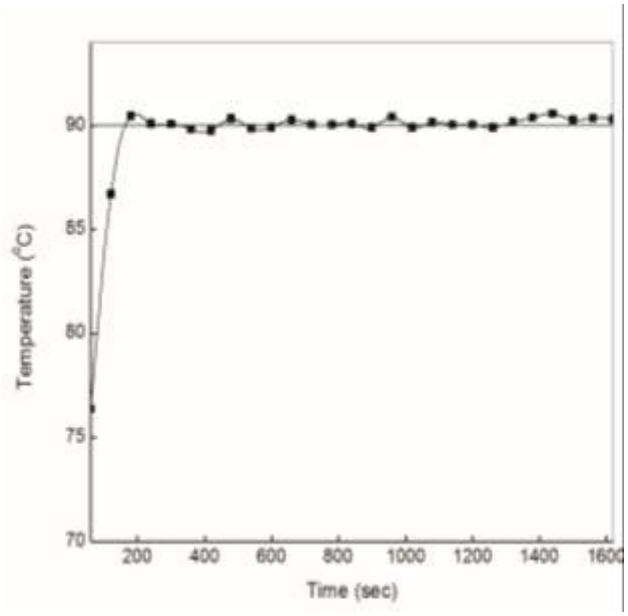

Fig. 4(b)
Fig 4. Response of the PID controller for set point (a) 60^0C and (b) 90^0C

It is found that the controller is able to control the temperature of copper block within $\pm 1^0$C.The PID controller gives a good transient as well as steady state control. It offers rapid proportional response to error, while having an automatic reset from the integral part to eliminate residual error. The derivative section stabilizes the controller and allows it to respond to the rapid changes or transients in error. However the actual stability, that has been attained in the present case depend on various factors such as the sensor sensitivity and thermal insulation of the heater etc. Usage of better sensor and proper insulation of the heater can play a significant role in accomplishing the theoretical limit of stability.

CONCLUSION

A PC based temperature controller is developed and successfully tested on a copper block wound with nichrome coil. The system is designed to be integrated in an ac conductivity set up. The controller is capable of maintaining the set temperature constant within $\pm 1^0$C.The PC based temperature controller is able to bring the temperature of the copper block to the desired value within 2 to 3 minutes of time. The system is quite successful in measuring and controlling the temperature. Its ability to perform different control functions without the use of any control circuits makes it versatile to be adapted in variety of application without much change. The control equations employed gives one the flexibility in programming and producing the different control signals for set-point control. Best control can be obtained by properly adjusting the PID parameters.

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