Automatic Temperature Control Technique for a Clinical Water Bath

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***Abstract*—The following paper is aimed at designing of a clinical water bath with an automated temperature control system. A temperature controller that maintains temperature of water at predefined value is attached to water bath which is a container. It is applied for incubation in microbiology or pathology laboratories. It is often observed that most of the water baths are manually controlled. Hence there seems need for automated temperature control. An automation is also done by using thermostat which is cheaper but the control band of thermostat is considerably wide, hence the variation of temperature about the predefined value is more. The proposed methodology eliminates wide variation of temperature about the pre-set value by controlling the amount of power input to the heater. Various temperature sensors were tested and LM 35 is used amongst them and the power input for heater is controlled in three bands namely 10 %, 50%, 100%. The task is done using microcontroller ATmega 16.**

Keywords- Temperature Sensor, Water Bath, Solid State Relay(SSR)

I. Introduction

Water bath which is nothing but a container device which holds water temperature at a defined value. It is used in the microbiology or pathology laboratories for incubation. A typical water bath has approximate capacity of five to ten litres. 10-12 test tubes can be fitted at a time. Ancient water baths were very bulky in size. The temperature was usually monitored manually using thermometers. Monitoring process was lengthy and time taking, moreover lot of attention was needed. Monitoring depended on human hence human errors were possible. Thermostat is applied in clinical water bath, where the temperature is retained by controlling power input to heater. Most of the water baths in general laboratories range through temperatures from +5 to 99.9°C. Many vendors [12] provide temperature pre-set buttons for quick selection of frequently used temperature set points. Choosing the right size water bath depends on the volume and size of samples. Water bath sizes can range from 1.5 to 43 litres. For comparing different bath volumes, it is best to compare internal tank dimensions. Cheapest laboratory baths are unstirred ones and have the least accuracy in temperature control because water is only circulated by convection and so is not uniformly heated. Temperature of stirred waterbaths are comparatively more accurate. They either can have in-built pump or circulator (some can pump the liquid externally into instrument and return into the bath). Shaking waterbaths have a speed controlled shaking platform tray (generally reciprocating motion i.e.backwards and forwards, although orbital motion is available with some brands) to which adapters can be added to hold different vessels. Available are ones which are cooled type water baths which come as integrated with cooling system (condenser,compressor, etc.) built into laboratory waterbaths. Other ones are with use of standard waterbath using a circulator with a separate cooling system such as an immersion coil or liquid circulated from a circulating cooler. The used immersion thermostat should be able to control at the below ambient temperature required.

A. *Related Work*

As per survey it is observed that most of the water baths used are manual in nature,and hence automated temperature controlling is the hour's need. Michael Marten has constructed a system which concurrently provides eight various temperature controls for nurturing aquatic organisms is presented with temperatures ranged from 4 to 18°C, plus and minus 2.3 intervals[1]. R. R. HENLEY developed a system using manual stirrer kettle and flame for particularly blood serum which needs particular temperature [2]. Omprakash Verma developed Water bath using fuzzy control system that uses fuzzy logic to control temperature [3]. Water bath is used to maintain temperature for conducting various tests. Also for experimental purpose in laboratory it can be utilized. Particular setting of temperature is required in components like Blood, Urine, Laboratory solutions and in testing of cancer tissues.

B. *Temperature Monitoring*

Water baths temperature can be set via control. This control could be dial or digital. Generally it is provided with an indicator light associated with this control. When the water bath is heating, the light turns on. When the water bath reaches the defined temperature, it will cycle on/off to hold set temperature. Temperature could be monitored or controlled manually or automatically.

1) Manual Monitoring: In manual temperature monitoring, temperature is monitored by a technician or a person, so continuous attention is required all the time. Sometimes it has no facility to give set point, hence increases chances of human errors.

2) Automatic Temperature Monitoring: Thermostat controlled water baths having easy to use digital temperature indicator, incorporated over temperature protection system that tracks the set temperature and regulates the heater. The heater is put underneath the tank to allow ease of cleaning. Included water sensor for low level which cuts the power preventing the bath to boil dry. Comprised with drain for ease in emptying the bath. Microprocessor technology and a temperature stability of 0.2°C, at a working temperature band of +20 to +99.9°C, are featured in water baths. There is an overall protection of splash-water and temperature settings a keypad with indication of temperature. Sensitive sample could be protected by features such as dry-running, visual and audible warning and shut-off features because they require a regulated environment.

II. METHODOLOGY

The system proposed consists of the temperature sensors, their selection, hardware and the algorithm for processing and displaying output result on display. Block diagram gives brief idea about the hardware as displayed in fig 1 .

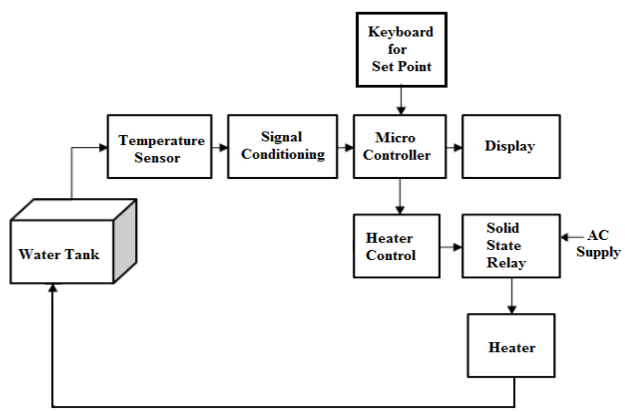

Fig. 1. Block Diagram

A. Specification of System

Designing of a particular system requires certain specifications so that the desired output will be more accurate. Water bath is a system which should retain constant temperature according to set point provided by user. Here required temperature range is 30 to 80°C. The proposed system is tested on the water tank with maximum 9 litre capacity.

B. Hardware Description

Different types of sensors like RTD, LM 35, thermistor (10 K ohm) were tested and characteristics of sensors are observed, the same are represented in fig 2. A suitable sensor LM 35 is selected and used in hardware. Selection of proper microcontroller and components required for amplification were selected. fig 1 shows the block diagram of the Clinical Water Bath and different components necessary for the system followed with an explanation.

1) Temperature Sensor: LM 35, Resistance Temperature Detector(RTD) and Thermistor are the sensors suitable for the range of 30 to 80°C[7]. Experimentations done using all three sensor showed that thermistor is comparatively nonlinear in nature. Also it needs separate excitation method. RTD gives output in resistance and then need to convert it to voltage for the further processing, so LM 35 [11] is selected whose sensitivity is 10 mV/°C. The following graph fig 2 shows comparison between the three sensors where the output response of each of the 3 sensors with the temperature change is plotted. Hence according to graph linear/non linear nature of sensors can be observed.

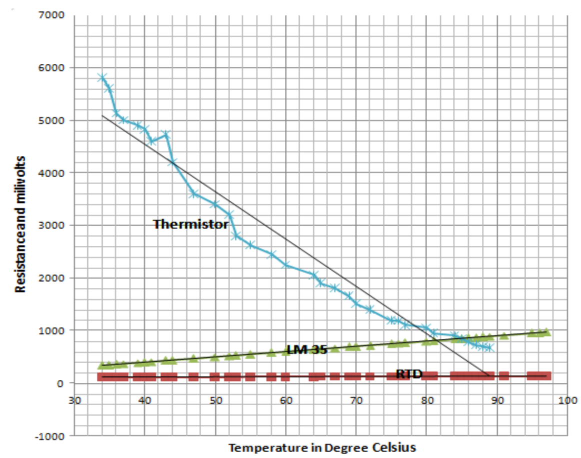

Fig. 2. Comparison of Temperature Sensors

2) Signal Conditioning: Signal conditioning is extensively used in the arena of data acquisition. Most common transducers generate an output in form of voltage, current, charge, capacitance and resistance. But those signals need to be transformed into voltage to match input to A/D converter. This conversion (treatment) is commonly called signal conditioning. Signal conditioning could be from current to voltage conversion or signal amplification. Here amplification of LM 35 signal needs to be done to interface with ADC. The maximum temperature of water bath can go to 100°C, that is output of sensor is 1000 mV, as LM 35 gives 10 mV /°C. The Amplification of signal is to be done as displayed in a following fig 3. Internal V-ref is 2.56 V and ADC is of 10 bits that means 1023 maximum counts provide 2.56 V. Hence for 100°Coutput, voltage should be 2.5 V.

$$ADCSensitivity = \frac{Vref}{2^n - 1}; = \frac{2.56}{1023}; = 2.5mV/count \tag{1}$$

Hence for 1000 count that is for 100.0 °C, the expected input for ADC should be

$$= 2.5mV \times 1000count = 2.5V \tag{2}$$

Hence it is clear that signal of LM 35 needs to be amplified by gain of 2.5

$$Gain = \frac{Vo}{Vi}; = \frac{2.5}{1}; = 2.5 \tag{3}$$

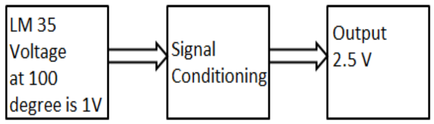

Fig. 3. Signal Conditioning

As the gain is more than 1 and no inversion is required non inverting configuration of operational amplifier is used. It also provides very high input resistance which minimizes loading errors. Gain of non-inverting amplifier is calculated and set as follows.

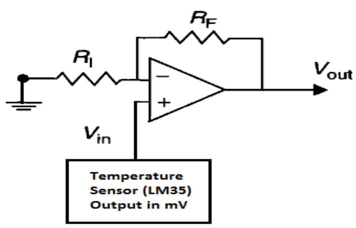

Fig. 4. Signal Conditioning Circuit

$$Gain = 1 + \frac{Rf}{Rin}; 2.5 = 1 + \frac{Rf}{Rin}; 2.5 - 1 = \frac{Rf}{Rin}; 1.5 = \frac{Rf}{Rin}; \quad (5)$$

For compensating errors in resistance, the variable resistor (10 K) is used in place of Rf and fixed resistance (5 K) is used in place of Rin.Hence the maximum adjust-ability is calculated as follows.

$$Gain(min) = 1 + \frac{Rfmin}{Rin} = 1 + \frac{0K}{5K} = 1; \quad (6)$$

(Since Rfmin =0 K);

$$Gain(max) = 1 + \frac{Rfmax}{Rin} = 1 + \frac{10K}{5K} = 3; \quad (7)$$

(Since Rfmax = 10 K);
Hence the gain of amplifier is trimmed to 2.5 by setting Rf properly. The non-inverting amplifier is implemented using LM 358 [10].

C. Heater Control

Temperature set point is entered through key pad [8]. Switching of circuit is controlled by solid state relay [15], solid state relay is optically isolated. It switches on at zero crossing of AC mains supply. The mains supply is an AC signal of 230V 50Hz which is converted to 0-5 V square wave using a rectifier, PC817 [14] opto isolator and 74HC14 as shown in fig 5. The output of 74HC14 is treated as clock input for 4017. CD4017 is a decoded output counter [5] which provides Q0 to Q9 output and carry output Cy. The Q0 and Cy produces 10% and 50% dutycycle in synchronism with mains signal which is steered through a control logic composed of 7432 [13], 7408 [16] and 74HC14. 10%, 50% and 100% control signals displayed in fig 5. driven by ATmega 16 [9] microcontroller. After receiving the value of set point , it continuously compares with current temperature, if temperature is reached, heater turnsoff. Fig 5 explains different dutycycles. When difference in set point and current temperature is more than 0.5°C, heater driven with 100% power. When difference in the set point and current temperature is less than 0.5°C, heater driven with 50 % power. When difference in set point and current temperature is less than 0.1°C, heater driven with 10% power. The power input to heater is controlled by using simple logic circuit displayed in fig 5.

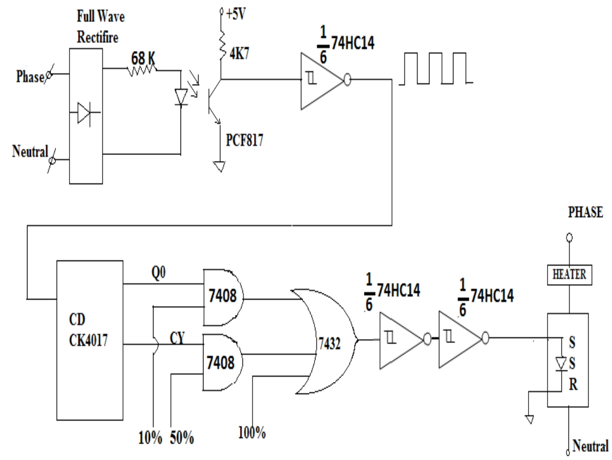

Fig. 5. Heater Control Circuit Using SSR

D. Microcontroller

The LM 35 output is given to in built A/D converter of microcontroller ATmega 16 [9]. The function of the microcontroller is to receive the data from A/D converter, process it and then display the value. The ATmega 16 is a high performing and low power CMOS-8 Bit microcontroller containing 8 K bytes of flash memory which is system programmable and 40 pin outs with four ports. Device is fabricated using Atmels highdensity nonvolatile memory technology. On-chip flash permits the memory of the program to reprogram in-system or by the traditional nonvolatile memory programmer. The ATmega 16 is strongpower micro-controller which caters a cost-effective,highly pliable solution for lot of embedded control applications. Port A of microcontroller acts as ADC where sensor's input is provided. Port B of microcontroller connected to keypad, Port C to LCD display and Port D to relay through heater control circuit.The circuit schematic of firmware is displayed in fig 6.

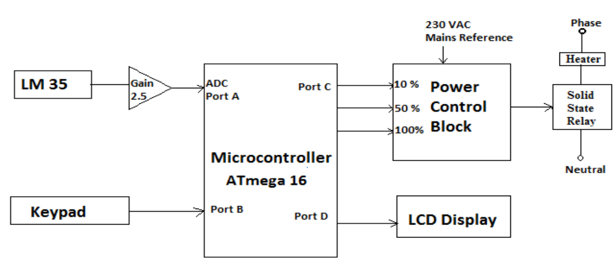

Fig. 6. Generalised Circuit Diagram of System

III. Conclusion

Selection of temperature sensor is done experimentally and LM 35 is selected. Water Bath is tested for a set point of 60°C. The performance is represented in a graph as displayed in fig 7. It is seen that the first overshoot reaches to set point +1°C, then temperature is controlled and maintained within span of 0.2°C, of the set point.

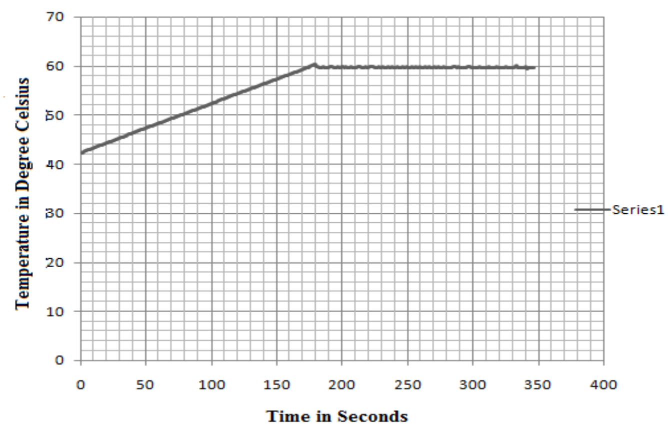

Fig. 7. Response of System

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