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Design of HMI Based on PID Control of Temperature

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Abstract: **One of the most used applications is Human Machine Interface in many industries. It has been recognized that our daily lives will be improved with various IOT applications in healthcare, agriculture, public sector, automation etc. Human Machine Interface that is HMI can be an example of IOT related applications. With web based GUI we can demonstrate HMI. The software components use here are Linux, Web based GUI, RL78 controller. To demonstrate industry application we put PID loop for control of temperature.**

Keywords: HMI, PID, QT, Temperature control, Thermocouple

I. INTRODUCTION

One of the most used application of Internet of Things is Human machine interface. For data management SQLite is used. Data to be stored are PID parameters, temperature data from RTD and Thermocouple. Temperature of plant can be maintained by PID loop in 16-bit controller. For PID control closed loop method Ziegler-Nichols can be used. Two techniques for controlling temperature are Manual Tuning and Auto tune PID. In manually tuned PID the control parameters are set manually by observing characteristics and behaviour of controlled device.

In Auto tuned PID controller automatically determines the behaviour of device from past samples. In Auto tune PID control parameters are set by controller automatically. We update these control data in database and we can observe temperature of plant in Beagle bone. Graphical User Interface (GUI) is developed in QT application. Design for display of set temperature and actual temperature is developed in QT at server.

II. WORKING OF HMI

The aim of this design is to monitor the status of plant from remote location. PID controller is used to maintain the temperature. There are two modes manually tune PID and auto tune for PID tuning. This temperature value is to be displayed on server through RS-485 serial communication.

MAX31855 IC is used as a convertor and uses SPI protocol to transfer temperature data to controller. The following is a Block Diagram for complete system. The parameters of PID controller can be set by HMI touch-screen display. Based on the difference between set temperature and actual temperature, PID controller gives output to minimize the error. The bulb released energy in the form of light and heat. Therefore, whenever actual temperature goes beyond set temperature bulb will be off. Hence, bulb will be on and off based on the PID output [1].

The parameters K_p, K_i and K_d plays a vital role in controlling PID controller output. These parameters are set based on the characteristic of actuator. For different actuators in different condition same parameters can't be work. The bulb will be continuously on and off to maintain the desired temperature.

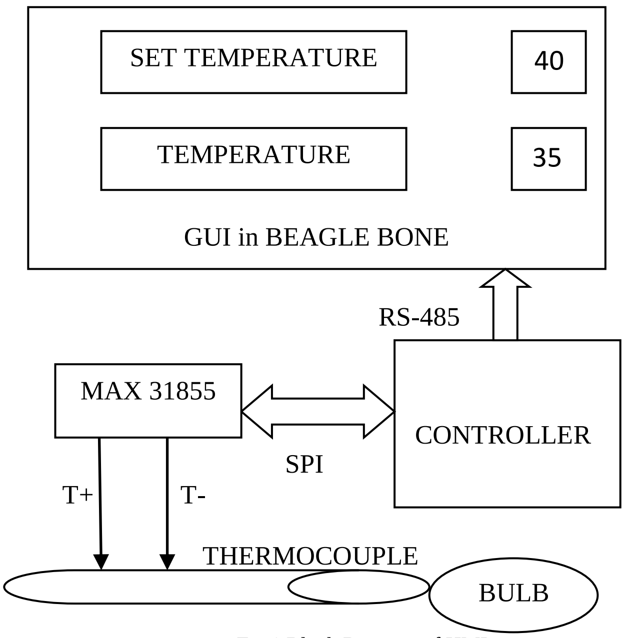

Fig.1 Block Diagram of HMI

These data of actual temperature and parameter values are stored in local database. Hence, whenever it needed HMI will get data easily. The actual temperature is

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transmitted to HMI through UART serial communication. User can set value of desired temperature and PID parameter values in case of manual tuning.

III. PID TUNING

There are many methods for tuning of PID controller for maintaining temperature. But most popular method for closed loop system is Ziegler-Nichols method. For many practical processes, this tuning approach works fine. However, sometimes it does not provide better tuning and tends to produce overshoot. Therefore, this method usually needs retuning before applied to control industrial processes [2].

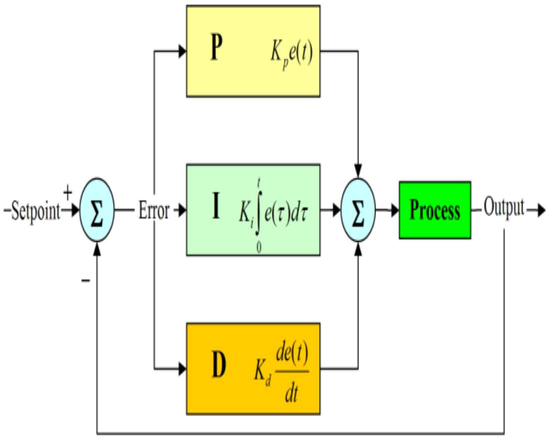

Fig.2 PID Block Diagram

PID stands for Proportional, Integral, Derivative control. A PID controller continuously calculates an error value as the desired set-point and a measured process variable and applies corrective action based on Proportional, Integral and Derivative terms [1].
Final output of PID is based on general equation:

$$\mathbf{U(t) = K_p * e(t) + K_i \int_0^t e(t) + K_d \frac{de(t)}{dt}} \qquad \mathbf{(1)}$$

Whereas, U(t) = PID output, e(t) = error at time t, K_p = Proportional gain, K_i = Integral Gain, K_d = Derivative gain.

A. Description about PID

There are three parameters Kp, Ki and Kd that are to be obtained for proper tuning. Desired temperature is set by user and PID controller try to adjust this temperature constant by using relays. For PID tuning characteristic and behaviour of bulb need to be identified.

B. PID Experimental Results

Observations of step change in duty cycle of output in open loop system are represented in graph.

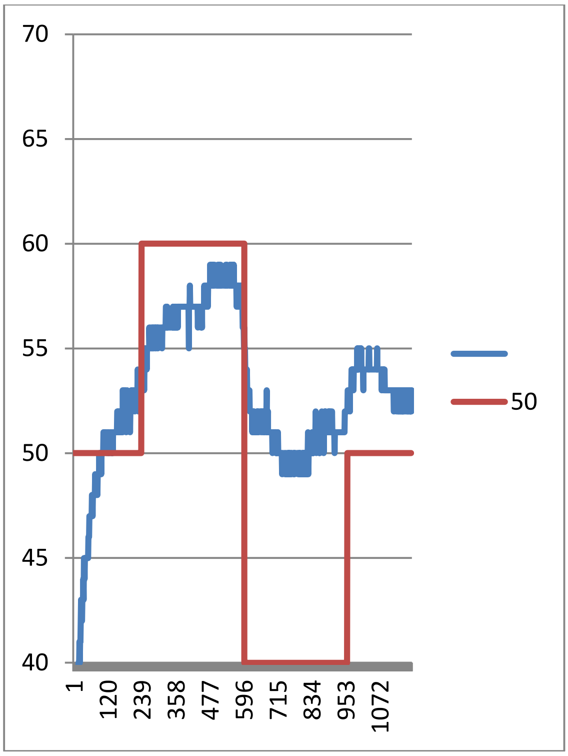

Fig.3 Actual Temperature v/s Time

Total 10 second is taken as window size. Then step change of 5 second ON time and 5 second OFF time which is 50% duty cycle and ratio is change by 60% and 40%. According to this ON-OFF time of bulb, temperature changes due to heat generated by bulb. The parameters critical gain Kc and time period Ti at which output becomes stable is obtained. From this, parameters closed loop parameters Kp, Ki and Kd are obtained from Ziegler-Nichols method. For classical PID tuning relationship between open loop parameters and Kp, Ki, Kd is following:

$$\mathbf{K_p = K_c,\ \ K_i = T_i/2,\ \ K_d = T_i/8} \qquad \mathbf{(2)}$$

The output of PID is compared with ON-OFF time of bulb. Hence, bulb will be ON and OFF to maintain the output of temperature constant at set value. The parameters K_p, K_i and K_d play a vital role in PID temperature control loop. The graphical analysis of actual PID control of bulb is following:

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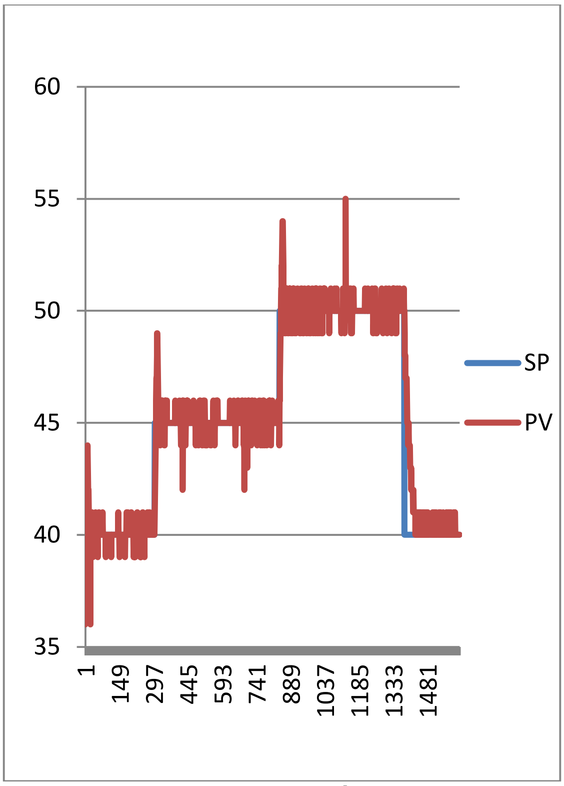

Fig.4 Temperature control using PID

Initially, set value of temperature is 40˚C and step change in set value is applied and new set values are 45˚C, 50˚C and 40˚C respectively. During this period present temperature tries to become stable at set value due to PID loop. If we further increase the value of proportional gain K_p value of highest spikes increases that means it increases oscillations. If value of K_i increases steady state error decreases.

The value of K_d effects the settling time of system. The integral action has the potential to increase the system accuracy, but an important aspect of the use of integral term is that it can lead to integral windup. It is a condition that results when integral action saturates a controller without the controller driving the error signal toward zero. It can results in excessive oscillation or even instability [3]. Hence, sometimes anti-wind up code needs to be added to decrease steady state error.

C. Thermocouple and SPI Interface

A Thermocouple is one type of sensor which is used for measurement of temperature. Thermocouples consist of two wires that creates junction and temperature is measured at this junction. When the temperature change occurs at junction, voltage is created. The voltage can be used by thermocouple reference tables to calculate the temperature. Thermocouple has two terminals T+ and T-.

The MAX31855 performs cold-junction compensation and digitizes the signal from a K, J, T, or E type thermocouple. This converter MAX31855 resolves temperatures to 0.25˚C, allows readings as high as +1800˚C and as low as -270˚C, and exhibits thermocouple accuracy of ±2˚C. Data output is signed 14-bit, SPI compatible [4].

For internal and external temperature we need 32 clocks continuously. Internal temperature contains 12-bit and for external temperature 14-bits are required.

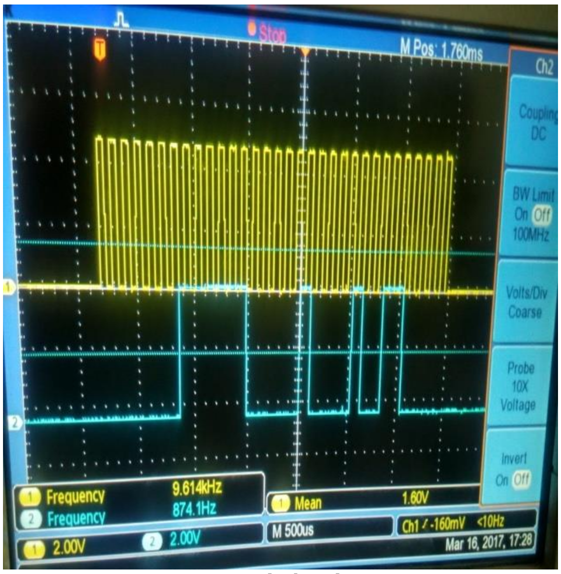

Fig.5 SPI clock and Data

V. QT APPLICATION FOR HMI DESIGN

With Qt cross-platform development, one can write and maintain one code base regardless of the platforms you choose and there's no need for separate implementations on different devices. When working with Qt, especially when developing cross-platform software, Qt Creator is use as IDE [5].

The GUI of HMI allows user to enter desired temperature value and PID parameters. There is a login screen for administrative login and user login. The administrator can change the PID parameters and desired temperature and user mode is for monitoring purpose.

Fig.6 Design of Plant controlled by PID

Set temperature is set by user. Actual temperature is obtained from plant over UART. By selecting the channel

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we can obtain the updated temperature data through UART. After successfully login in to system one can monitor and set values for set temperature. According to set value, PID controller tries to maintain Actual temperature similar to set temperature.

VI. CONCLUSION

This paper describes PID loop for temperature control. One of the famous Ziegler-Nichols method for PID tuning is discussed. There are some other methods for PID tuning and for that we get different results for PID parameters. Experimental and theory results for PID loop are nearer and PID loop is working for temperature control. HMI design can be modify according to need of channels and different types of users.

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