# Design of PID Controller Using Modified Relay base Ziegler Nichols Method

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***Abstract***— This Paper concerned with the designing a low cost PID temperature controller. Because of their simplicity, robustness and successful practical application, PID controllers are the most popular and widely-used controllers in industry. Many PID design methods have been proposed, each has its advantages and limitations. However finding appropriate parameters for the PID controller is still not easy task. The objective is to achieving an important design compromise, acceptable stability, linearity and medium fastness of response. In this paper, Atmega128 has been used as a brain to the prototype. PID controller has been selected as a controller because it has faster response than the conventional on-off controller. The experimental result reveals that the PID controller can be implemented into the low cost prototype and able to control the temperature according to standard regulation.

**Keywords:** proportional integral derivative (PID), Resistance Temperature Detectors (RTD), Control Loop Tuning, Ziegler-Nichols Tuning.

## I. INTRODUCTION

The PID control algorithm is one of the most popular approaches for industrial field to apply in the process control systems. The main reason why PID is the main popular method of control in industry is because the simple structure of the PID itself, it also conceptually easy to understand and makes the manual tuning is possible. PID is proportional integral and derivative controller which is a linear combination of the input, the derivative of input and integral of input.

This paper discuss about both method of Ziegler-Nichols. Second method is modified to get optimized performance. It also contain all on –off , P, PI, and PID Controller result with particular system.

## II. THE BASICS OF ON/OFF CONTROL

In this simple form of control, the controller output switches off when the process temperature reaches the SP. And the controller output switches on till it reach up to set point. So controller output always 0 % or 100%.

Hear in above example I set 1100 C The heater is completely ON when temperature below 1100 C. And heater is completely OFF when temperature above 1100 C. You can see that Sustain oscillation achieve in this type of controller but user not achieve exact 1100 C SP. Advantage of this type of controller is simplest .And Typical Applications are Air conditioning, Oil heaters, Bain Marie catering , equipment.

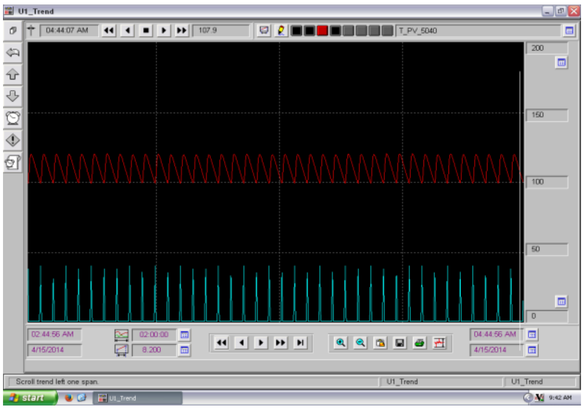

Fig. 1: On-Off controller Response.

## III. THE BASICS OF PID CONTROL

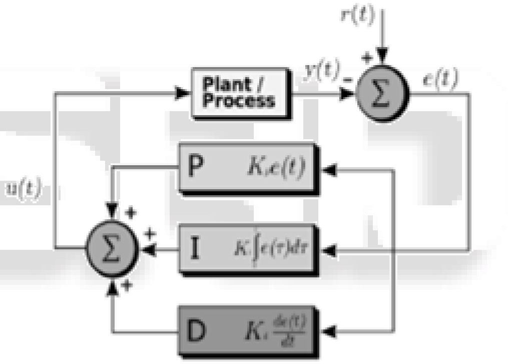


Fig. 2: Basic Block Diagram of PID Controller

A proportional-integral-derivative controller (PID controller) is a common feedback loop component in industrial control systems.

The controller takes a measured value from a process or other apparatus and compares it with a reference set point value. The difference (or "error" signal) is then used to adjust some input to the process in order to bring the process measured value back to its desired set point. Unlike simple controller, the PID can adjust process outputs based on the history and rate of change of the error signal, which gives more accurate and stable control. PID controllers do not require advanced mathematics to design and can be easily adjusted (or "tuned") to the desired application, unlike more complicated control algorithms based on optimal control theory.

### *A. Derivation of a Continue-time algorithm for a PID controller*

The generic equation for a PID controller in the time-continuous domain is

$$U(t) = Kp\, e(t) + Ki \int_0^t e(t)\, d(t) + Kd \frac{d\, e(t)}{dt} \quad ….(3.1)$$

 

Where,

U = Controller Output

PV = Process value =Measure value

SP = Set Point

Kp = Proportional gain, a tuning parameter

Ki = Integral gain, a tuning parameter

= Kp/ti

Kd = Derivative gain, a tuning parameter

= Kp* td

e: Error = S.P –P.V

t: Time or instantaneous time (the present)

*Proportional term*

Poutput = $K_p\, e(t)$ ……(3.2)

*Integral term*

Ioutput = Ki $\int_0^t e(t)\, d(t)$ ……(3.3)

*Derivative term*

Doutput = Kd $\frac{d\,e(t)}{dt}$….(3.4)

Finally,

U(t(k)) = Kp e(t(k)) + Ki $\sum_{i=1}^{K} e(t(k))\Delta t$ + Kd * [e(t(k)) - e(t(k-1))]/ Δt …….. (3.6)

PID Output = Poutput + Ioutput + Doutput ..(3.5)

*Simplified Discrete PID Equation.*

## IV. PID TUNING METHOD: ZIEGLER NICHOLS TUNING

Basically, Ziegler Nichols tuning method is one of the several types of tuning method exist in control systems. This type of tuning method is proposed by Ziegler and Nichols in the 1940s and this type of tuning method largely based on certain assumed model.

Tuning a control loop is the adjustment of its control parameters (gain/proportional band, integral gain/reset, derivative gain/rate) to the optimum values for the desired control response. Stability (bounded oscillation) is a basic requirement, but beyond that, different systems have different behavior, different applications have different requirements, and requirements may conflict with one another.

PID tuning is a difficult problem, even though there are only three parameters and in principle is simple to describe, because it must satisfy complex criteria with in the limitations of PID control. There are accordingly various methods for loop tuning and more sophisticated techniques are the subject of patents.

C(s) = Kp + Ki/s + Kd * s …….(4.1)

C(s) = Kp [ 1 + 1 / (Ti * s) + Td *s ] ……..(4.2)

where,

Kp = proportional gain

Ki = integral gain = Kp/Ti

Kd = derivative gain = Kp / Td

Ti = reset time

Td = rate time or derivative time

The proportional term used in the controller generally helps in establishing system stability and improving the transient response while the derivative term is often used to improve the closed response speed when it is necessary to use. Theoretically, the effect of the derivative term is to feed information on the rate of change of the measured variable into the controller action. The most important term in the controller is the integrator term that introduced in the forward loop process

Based on the below Figure, there is some equation below that may explain the PID controller function

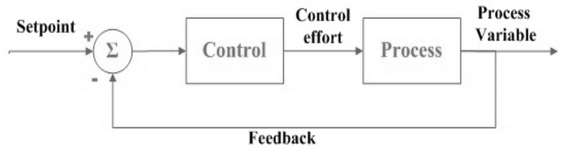


Fig. 3: PID controller block diagram

U(t) = Kp e(t) + Ki $\int_0^t e(t)\, d(t)$ + Kd $\frac{d\,e(t)}{dt}$ ….(4.3)

Error = S.P –P.V …….(4.4)

### *A. Ziegler Nichols First Method- from step response (Open loop Method)*

Below Table is the first method of Ziegler and Nichols used to tune PID controller. This type of response is typical of first order system with some transportation delay such as fluid flow and heat. The model of the plant is

G(s) = K e-SL / (TS + 1) ……(4.5)

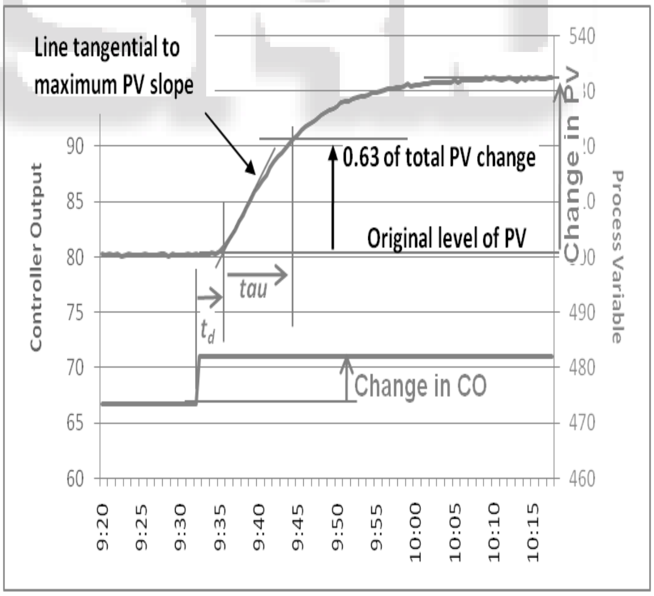


Fig. 3: Ziegler Nichols First Method- from step response

Calculate the process gain (gp) as follows:

*gp = change in PV [in %] / change in CO [in %]*

Calculate settings for Controller Gain (Kc), Integral Time (Ti), and Derivative Time (Td), using the Ziegler-Nichols tuning rules below. Note that these rules produce a quarter-amplitude damping response and the calculated controller gain values should be divided by two.

*For P control: Kc = tau / (gp * td)*

*For PI control: Kc = 0.9 * tau / (gp * td);*

*Ti = 3.33 * td*

*For PID control: Kc = 1.2 * tau / (gp * td);*

*Ti = 2 * td;*

*Td = 0.5 * td*

### *B. Ziegler Nichols Second Method from frequency response (Close loop Method)*

To render under proportional control, the second method can be used. These techniques specially develop to result in a closed loop system with 25% of overshoot.

Some step must be taken for tuning PID controller via the second method.

In the Second method, First set Ti = and Td = 0.Using the proportional control action only. Increase Kp from 0 to a critical value Ku where the output first exhibits sustained oscillation. (If the output does not exhibit sustain oscillation for whatever value of Kp may take, this method does not apply).

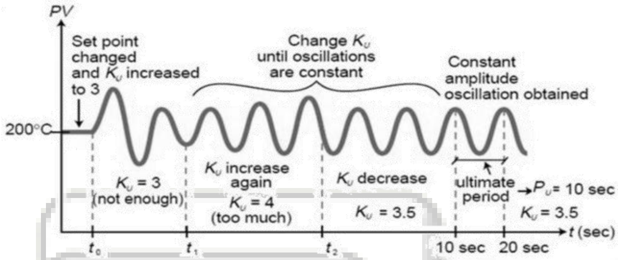


Fig. 5: Ziegler Nichols Second Method from frequency response.

Using the ultimate gain Ku and the corresponding period Pu, Ziegler and Nichols suggested setting the values of the parameters Kp, Ti and Td according to the formula shown in Table.

| Controller Type | $K_p$ | $T_i$ | $T_d$ |
|---|---|---|---|
| P | 0.5 $K_u$ | Infinity | 0 |
| PI | 0.45 $K_u$ | 0.833 $P_u$ | 0 |
| PID | 0.6 $K_u$ | 0.5 $P_u$ | 0.125 $P_u$ |

Table. 1: Ziegler Nichols Tuning Rules Based On Ultimate Gain Ku and Period Pu

It is an easy experiment; only need to change the P controller But Below are some disadvantage.

Disadvantages:

Experiment can be time consuming . Second, It can venture into unstable regions while testing the P controller, which could cause the system to become out of control. Third, For some cases it might result in aggressive gain and overshoot.

### *C. Relay base Ziegler Nichols Method*

To overcome above Problem I used Relay base Ziegler Nichols method. In which we not need to continue change Ku for sustained oscillation. Instead sustained oscillation achieve through Relay completely on and off.

To get sustained oscillation, initially it behave simple on off controller. This period is known as Auto Tune Period. After that it work PID controller. In Auto tune Period Ultimate gain Ku and Period Pu achieve.

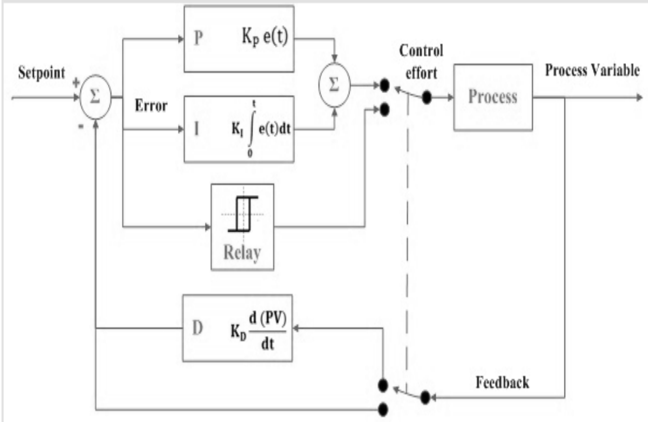


Fig. 6: Block diagram of Relay base Ziegler Nichols Method

In above figure its not achieve sustain oscillation from first cycle. But first cycle is not sustain oscillation.so it ignore and from second cycle Parameter calculate. Below figure is actual output of my system.

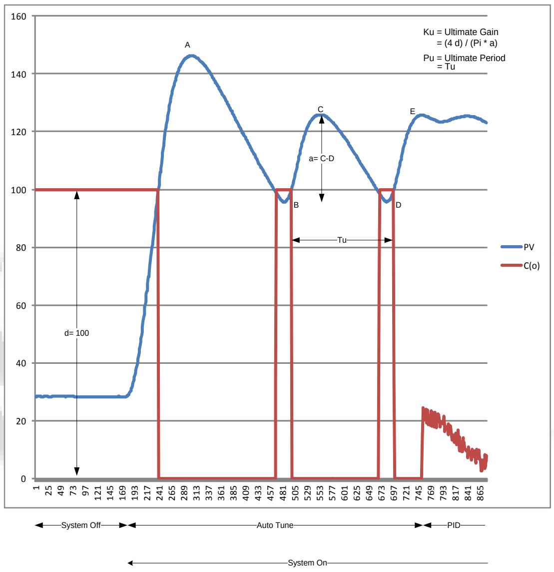


Fig. 7: Auto tune cycle for PID controller

Hear I explain three type of controller P, PI and PID.

In all controller PB is most importance. Which is stand for Proportional Band.

PB= 100/Ku.

#### *1) P Controller*

| PB | SP | Low Band | Upp Band | Kp |
|---|---|---|---|---|
| 94.5 | 100 | 52.75 | 147.25 | 1.058201 |

Table. 2 : Lower Band and Upper band Calculation

| PV | PV - Low band | (PV - Low band)*Kp | C(o) |
|---|---|---|---|
| 52.75 | 0 | 0 | 100 |
| 75 | 22.25 | 23.54 | 76.45 |
| 100 | 47.25 | 50 | 50 |
| 132 | 79.25 | 83.86 | 16.13 |

 

| | | | |
|---|---|---|---|
| 147.25 | 94.50 | 100 | 0 |

Table. 3: Output of P type controller

Hear , as shown above PB is 94.5 and I set SP=100. The output of system is shown in below.

As show in graph output not set 100 but instead it set around 132. So System have some offset. This offset is remove through manual reset. This offset present only P-type controller. Manual reset (MR) is nothing but its shift Band.so that user can achieve exact SP.

| **PB** | 50 | **SP** | 100 |
|---|---|---|---|
| MR=0 | | MR=25 | |
| **PV** | **c(o)** | **PV** | **c(o)** |
| <=75 | 100% | <=100 | 100% |
| 100 | 50% | 125 | 50% |
| >=125 | 0% | >=150 | 0% |

Table. 4: Effect of Manual reset in P-type controller

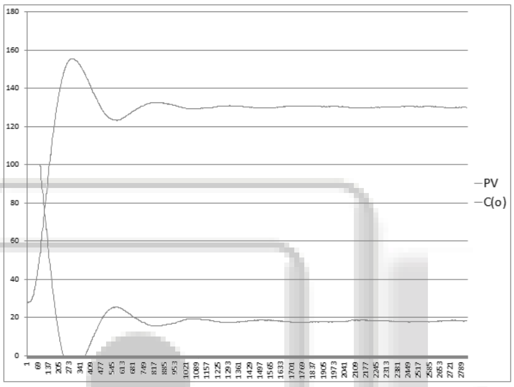


Fig. 8: Practical P - type Controller Response

*2) PI controller*

It is most widely used To compensate for the offset resulting in proportional only control, a second control term known as Integral Action is introduced. Integral Action eliminates the offset by responding to duration of the error signal (through integration) and automatically forcing the process temperature to settle exactly at the set point after a period of time. This is achieved by small adjustments in the proportional output. Below graph is same of above system but Hear I_Output is added. I set SP = 100.

PB=94.5 and ti=225 and sampling time t=200 mS.

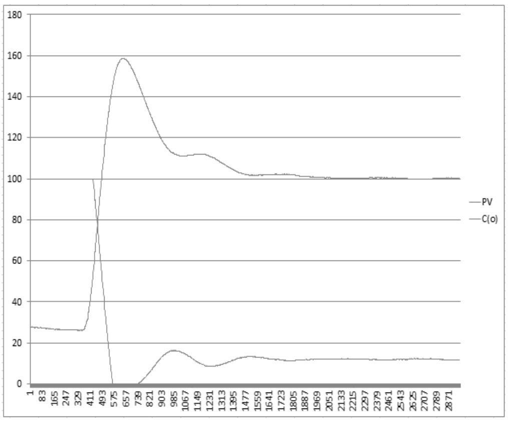


Fig. 9: Practical PI - type Controller Response

*3) PID controller*

In many small capacity processes, the controller must respond quickly to large and rapid changes in temperature caused by disturbances. Derivative action provides additional temperature stability by reacting to the rate of change of the process temperature. But it is not widely use in temperature system .like PI controller Below graph is same system is above controller . . I set SP = 100 PB=94.5 ,td =56, ti=225 and sampling time t=200 ms.

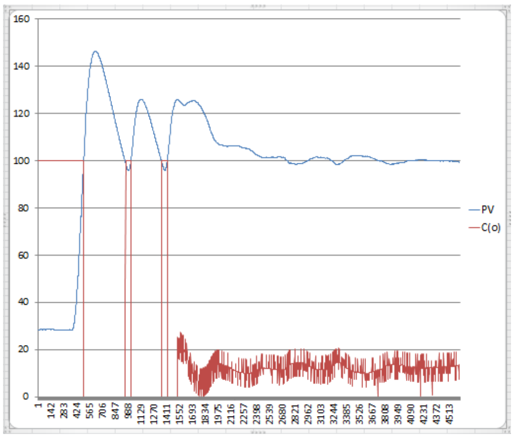


Fig. 10: Practical PID - type Controller Response

## V. CONCLUSIONS

All results in this paper are with same system and same input type which is RTD Input type. Hear result reveals that PI controller has Low Rise time, small overshoot, fast settling time and No steady state error. So its widely used in Industries.

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