PID temperature controller DIY Arduino

IDEA:

Building a PID temperature controller DIY Arduino. In our PID temperature controller DIY Arduino we will be measuring the temperature, humidity, and we control them to maintain a certain amount of desired level.

PROJECT APPLICATION SCENARIO:

- Heat treatment of metals
- Drying/evaporating solvents from painted surfaces
- Curing rubber
- Baking

Temperature Control System and its Control using PID Controller:

Literature survey

Temperature control is required in nearly each and every field of application such as household, industrial, research and other such applications. In this paper, we present the mathematical modelling of temperature control system and its control using PID controller. Based on the experimental data taken in the laboratory, we develop a transfer function model of an oven under observation and then design a PID controller in order to improve its step response characteristics. The temperature control system is used widely in industries. In this, the plant is an electric oven or a heater whose temperature is to be controlled with respect to the reference input and control. In this literature review, the mathematical modelling of an electrical oven and its tuning using a PID controller is explained.

In temperature control system, there is the transfer of heat from the heater coil to the oven and the leakage of heat from the oven to the atmosphere. There are three modes of heat transfer viz. Conduction, convection and radiation. Heat transfer through radiation may be neglected in the present. For conductive and convective heat transfer is given by

equation (1)

$\theta = \alpha \, \Delta T$ (1) Where, θ is the rate of heat flow in joule/sec

ΔT = temperature difference in

α = constant

Under assumptions of linearity, the thermal resistance is defined as

R= temperature difference/ rate of heat flow = $(\theta/ \Delta T)$.

This is analogous to electrical resistance defined by I=V/R.

In the similar pattern thermal capacitance of the mass is given by equation (2)

$\theta = C \, d(\Delta T)/dt$ (2)

Which is analogous to the V-I relationship of a capacitor, namely I=CdV/dt. In the case of heat,

C= rate of heat flow /rate of temperature change.

The equation of an oven may now be written by combining the above two equations, implying that a part of the heat input is used in increasing the temperature of the oven and the rest goes out of loss. Thus

$\theta = C \, d(T)/dt + R\text{-}1T$ (3)

With an initial condition T(t=0) =Tamb. Now, taking Laplace transform with zero initial condition

$T(s)/ \theta(s) = R/(1+sCR)$

II. PID CONTROLLER

PID controller is the most widely used controller in the industry. A PID controller has three parameters- proportional constant ‘KP’, integral constant ‘KI’ and the derivative constant ‘KD’. These three parameters are meant to take care of the present, future and the past errors. A PID controlled process having system transfer function ‘Gs’ and unity feedback is shown in Fig. 1.

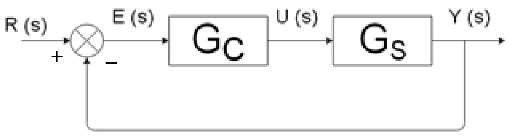


Fig.1. PID Controller

'Gc' is the transfer function of the PID controller and is given by equation (4) and (5)

$$G_c = K_P + \frac{K_I}{s} + K_D s \tag{4}$$

$$G_c = K_P\left(1 + \frac{1}{T_i s} + T_d s\right) \tag{5}$$

Proportional action is meant to minimize the instantaneous errors. However, by itself it cannot make the error zero and provides a limited performance. The integral action forces the steady state error to zero, but has two disadvantages: due to the presence of a pole at the origin, it may result in system instability and the integral action may create an undesirable effect known as wind-up in the presence of actuator saturation. The derivative action acts on the rate of change of error and it may result in large control signals when the error signal is of high frequency.

III. TRANSFER FUNCTION MODEL OF THE TEMPERATURE CONTROL SYSTEM

The step response of the open loop system is obtained and the experimental data. From the step response of the open loop system, the transfer function model is obtained and is given by equation (6).

$$G(s) = \frac{104e^{-2.6s}}{1+15.783s} \tag{6}$$

IV. CONTROL USING PID CONTROLLER

The process of selecting the controller parameters to meet given performance specifications is known as controller tuning. Ziegler and Nicholas [2] suggested rules for tuning PID controllers (meaning to set values Kp, Ti and Td) based on experimental step responses or based on the value of Kp that results in marginal stability when only proportional control action is used. Ziegler–Nichols rules, which are briefly presented here, are useful when mathematical models of plants are not known. There are two methods called Ziegler–Nicholas tuning rules: the first method and the second method.

A. First Method:

This method applies if the response to a step input exhibits an S-shaped curve. Such step-response curves may be generated experimentally or from a dynamic simulation of the plant. The S-shaped curve may be characterized by two constants, delay time L and time constant T. The delay time and time constant are determined by drawing a tangent line at the inflection point of the S-shaped curve and determining the intersections of the tangent line with the time axis and line

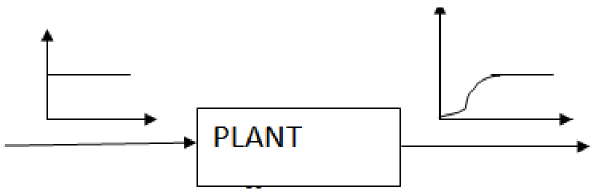
$c(t)=K$, as shown in Fig. 2. The parameters of the PID are

taken as:

$K_p = 1.2\,(T/L)$

$T_i = 2L$

$T_d = 0.5L$



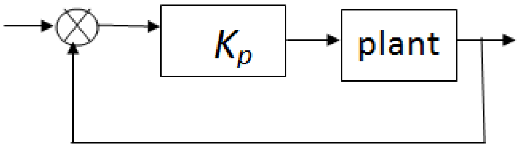
B. Second Method:

In the second method, we first set $T_i = \infty$ and $T_d = 0$. Using the proportional control action only, we increase Kp from 0 to a critical value Kcr at which the output exhibits sustained oscillations. Thus, the critical gain Kcr and the corresponding period Pcr are experimentally determined. Ziegler and Nicholas suggested that we set the values of the parameters Kp, Ti , and Td according to the formula shown below:

$K_p = 0.6\,K_{cr}$

$T_i = 0.5P_{cr}$

Td = 0.125Pcr



Conclusion:

The reviewed literature suggests that the main objective is the transfer function model of a temperature control system. The step response characteristics of the system can be improved by using a PID controller. Ziegler-Nicolas tuning methods were discussed and using the plant model, the parameters of the PID controller were determined. Comparison of the open loop response of the system with respect to the closed loop response shows a significant improvement in the step response characteristics.

Yugal K. Singh, Jayendra Kumar, Keshav K. Pandey, Rohit K. and Bhargav. A

Dept. of Electrical and Electronics Engg.,

RVS College of Engineering and Technology,

Jamshedpur-831012, INDIA

Business solution in industrial scenario and Comparative Analysis:

We can utilize this regulator to control the temperature in research facilities so the things don't neglect to work. The different types of PID based temperature controllers are:

PID loop tuning is used in a variety of temperature controllers and for varying numbers of loops. The most basic setup is for one temperature controller to calculate the PID and manage a single process. Medical cleaning equipment often uses a single loop PID temperature controller to ensure that the process runs at the right temperature for long enough to properly sterilise implements. A temperature sensor would measure the temperature inside the sterilising tank, which the PID temperature controller would then interpret and use to increase or decrease power to the heating element.

A more complicated temperature controller PID setup is multiloop, in which a single temperature controller manages several processes simultaneously. However, each process is discrete and therefore operates on individual loops, so a disturbance on one process will have no impact on another. For example, a bakery might have several ovens operating with the same setpoint, but not affecting each other, which would be run by a multiloop PID temperature controller.

PID Controllers with Cascade Control Loops

Some PID temperature controllers have enhanced capabilities which allow them to operate multiple loops that relate to each other, rather than each loop operating discreetly under central control. Cascade control is where two control loops operate in relation to each other in the form of a primary and secondary loop. The primary loop controls the main element of the process being heated; however, it does not have a direct heating element working on it. Instead, there is a secondary element that is often a jacket around the first and is controlled by a heating element. The PID controller measures both the primary and secondary loops and adjusts the power level affecting the heat of the secondary element so that it in turn heats the primary element to the setpoint.

The PID tuning in cascade loops is essential as otherwise there can be excessive overshoot waiting for the primary element to reach the setpoint. The PID controller reduces power as the temperature approaches the setpoint to meet and then maintain the setpoint. A familiar example for this is melting chocolate, where if chocolate is directly exposed to heat it is likely to burn, but it can be melted in a bowl over hot water. The chocolate is the primary loop, the delicate substance which ultimately needs to be heated, and the bowl of water is the secondary loop, the intermediary between heat application and the primary loop. Cascade loops work on the same principle, but at a much larger scale and with precise temperature control.

Multi-Zone Temperature PID Control

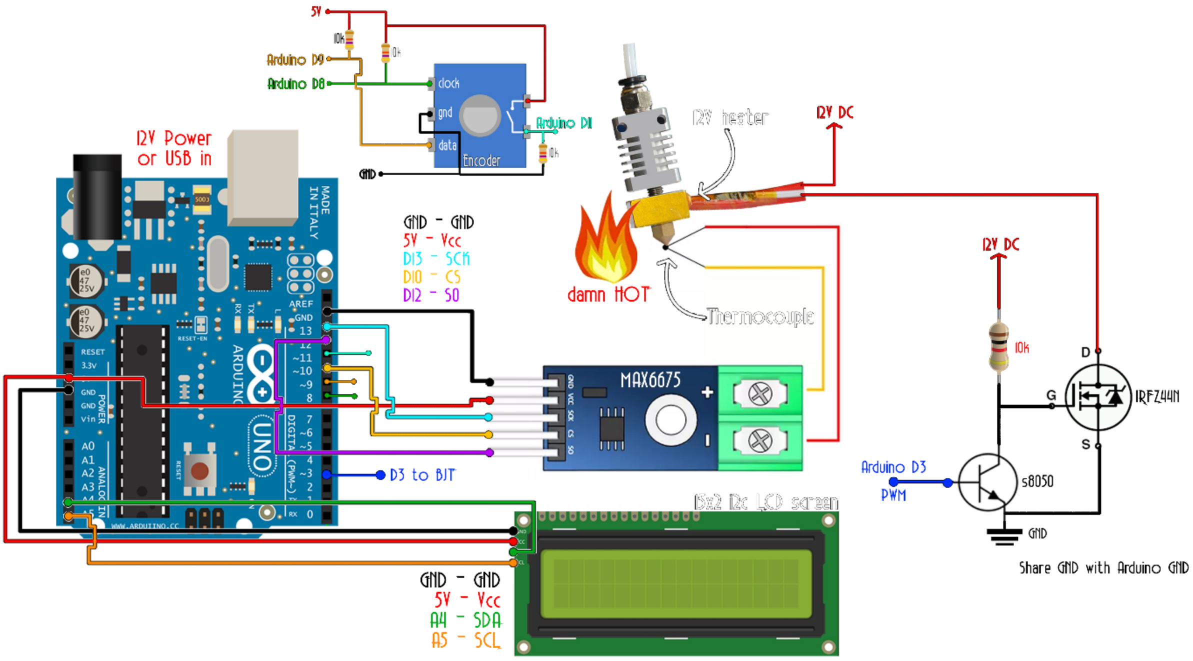
Multiloop PID temperature controllers are also valuable for managing multi-zone processes in which there is a single process to be managed, but the heating element is so large there can be temperature discrepancies between one area and another.

For example, in an industrial oven with six different heating elements, the temperature should be consistent across the entire oven, but the different elements might cause some areas to be hotter than others. As the process requires a uniform temperature the solution is to use a multiloop PID temperature controller to operate all six heating elements, so there are effectively six control loops running simultaneously. The PID controller can then adjust the power to each heating element individually to maintain the setpoint across all heating zones in the oven.

Architecture of IoT:

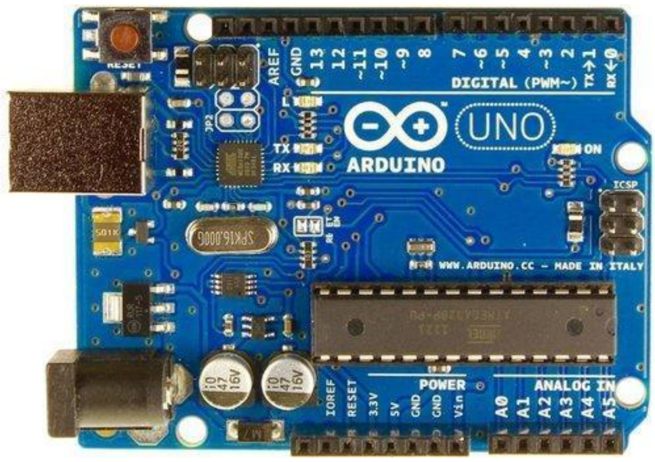
The IoT architecture for the system consists of three stages: physical, communication, and application. The first layer features a multiple-sensor network that evaluates the temperature of the heating element. The second layer includes OT devices that collect the information gathered by the sensors, translate it into meaningful data streams and transfer them to a back-end destination. The third layer is where data is received, stored, and processed using cloud-based data analysis engines and machine learning mechanisms. The resulting insights can be used to recommend the proper service for each specific situation or applied in further research or management purposes.

Connection diagram:



List of components:

- **Arduino Board (Uno)**
  The Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack and a reset button.



- **MAX6675 Sensor:**
  The MAX6675 performs cold-junction compensation and digitizes the signal from a type-K thermocouple. The data is output in a 12-bit resolution, SPI-compatible, read-only format.

- **9V Battery**
  To provide supply for the Arduino

- **Jumper Wires**
  Used for connecting the pins.

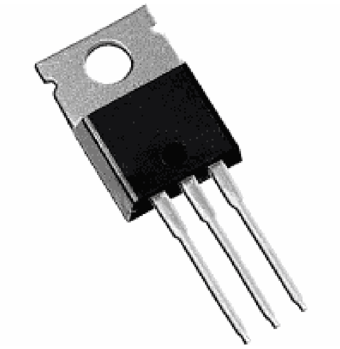
- **12V Heater**
  To act as the heating element whose temperature will be varied.

- **Rotary Encoder**
  To provide the set point for the input of the temperature.

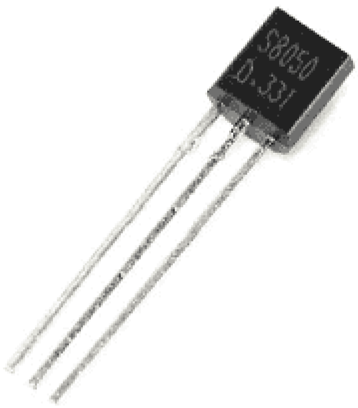
- **K Thermocouple**
  To detect the change in temperature of the desired material. A Type K thermocouple refers to any temperature sensor containing Chromel and Alumel conductors, that meets the output requirements as stated in ANSI/ASTM E230 or IEC 60584 for Type K thermocouples. This may be an immersion sensor, a surface sensor, wire or another style of sensor or cable.

- **9V Battery**
  To provide supply for the Motor Driver

- **IRFZ44N MOSFET**
  To provide the power to be delivered to the heating element or heater output.

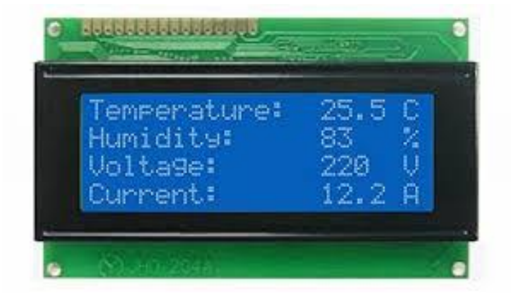


- **s8050 BJT**
  To provide the power to be delivered to the heating element or heater output.



- **10K Resistors**
  To provide the power to be delivered to the heating element or heater output by resisting the current flow.

- **LCD Display**
  To display the parameters on the screen for observation purposes.



Order the Components:

To be acquired as per requirements of the project.

Flowchart: