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Cloth iron with electronic control

Diplomová práce

Studijní program: N2301 – Mechanical Engineering
Studijní obor: 2302T010 – Machines and Equipment Design

Autor práce: **Vishnu Srinivasa Setty**
Vedoucí práce: Ing. Michal Moučka, Ph.D.

Liberec 2018

TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Mechanical Engineering

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Master thesis

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Author: **Vishnu Srinivasa Setty**
Supervisor: Ing. Michal Moučka, Ph.D.

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DIPLOMA THESIS ASSIGNMENT

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First name and surname: **Vishnu Srinivasa Setty**

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Topic name:

Assigning department: **Department of Manufacturing Systems and Automation**

R u l e s   f o r   e l a b o r a t i o n :

1. Get familiar with the conventional iron for ironing of clothes. Perform structural and dimensional analysis of the clothes iron.
2. Design an electronic circuit based on a single-chip microcontroller (PIC24F family or other) for temperature control. Choose the location of sensors and circuits appropriately.
3. Produce a printed circuit board (PCB) for temperature control of the clothes iron. The proposal must be based on dimensional analysis. Program the microcontroller.
4. Measure necessary dynamic characteristics to calculate optimal controller parameters. Calculate these parameters and implement them.
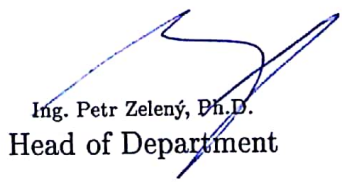5. Verify the functionality and appropriateness of your solution.

Scope of graphic works: **according to need**

Scope of work report
(scope of dissertation): **approx. 45 pages + attachments**

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List of specialized literature:

[1] MODRLAK O., L. HUBKA Automatic control in mechatronics. Liberec: Technical University of Liberec, 2014. ISBN 978-80-7494-175-7.
[2] RAVEN F. H. Automatic control engineering. New York: McGraw-Hill, 1995. ISBN 0-07-051341-4.
[3] SILVA C. W. Mechatronics. An integrated approach. Boca Raton: CRC Press, 2005. ISBN 0-8493-1274-4.
[4] HOROWITZ P., W. HILL The art of electronics (second edition). Cambridge: Cambridge University Press, 2008. ISBN 978-0-521-37095-0.
[5] VERLE M. PIC Microcontrollers - Programming in C. Belegrad: MikroElektronika, 2009. ISBN 978-86-84417-17-8.
[6] MILIVOJEVIC Z., D. SAPONJIC Programming dsPIC MCUS in C. Belegrad: MikroElektronika, 2009.

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ABSTRACT

To accomplish a specific task Just like any other technology, the ironing of clothes using iron box has gone through many iterations ever since its first inspectional appearances in Europe during the 1300's to today's modern iron box.

My diploma thesis focuses on changing the control technology from analogue to digital control of electric power supply to the heating coil of the iron box. The advantages that are attained by doing so are may to mention one, the temperature control could be attained$\pm5\,^{\circ}\mathrm{C}$. This massive task is achieved obtaining a traditional dry iron box and analysing its dimensions and, in the process, understand the working of the knob and disassembling it very carefully and determine the positioning of the thermistor (temperature sensor) on the base plate. The next logical step to attain this will be to equip it with the microprocessor and performing the necessary programming functions like configuring the registers of the chosen microprocessors and then determining the control element TRIAC, power transformers, or other alternatives. All the alternatives are considered their advantages and disadvantages are validated and appropriate device is chosen. Additionally, a 5V, 2Amps ADC adapter is used to provide safety for the circuits and processor. In the next stage a printed circuit board is developed, and all the components and the processor are mounted. The iron box is reassembled and tested for accuracy of the temperature.

Keywords: LCD (Liquid Crystal Display), temperature, PCB, TRIAC (BT138), temperature sensor, programming.

ANOTACE

Stejně jako jakákoli jiná technologie, tak žehlení oděvů pomocí žehličky prošlo řadou vývojových stupňů od svého prvního představení v Evropě v roce 1300 až po dnešní moderní žehličku.

Tato diplomová práce je zaměřena na změnu ovládání z analogového na digitální řízení. Napájení je realizováno elektrickým proudem v topné cívce v žehličce. Výhod, které budou dosaženy změnou ovládání, může být několik, PID regulací teploty lze dosáhnout přesnosti ± 5 °C. Tohoto výsledku je dosaženo použitím tradiční konstrukce žehličky, analýzou jejích rozměrů a procesu, pochopením fungování regulace, rozebrání žehličky a určení polohy snímače teploty na základní desce. Dalším logickým krokem k dosažení tohoto cíle je realizace mikroprocesoru a nastavení nezbytných programovacích funkcí, jako je konfigurace registrů vybraných mikroprocesorů a následné určení řídicího prvku TRIAC, výkonových transformátorů nebo jiných alternativ. Všechny alternativy jsou porovnávány dle jejich výhod a nevýhod a jsou validovány. Je vybráno vhodné zařízení. Adaptér ADC 5V, 2Amps je použit pro zajištění bezpečnosti obvodů a procesoru. V další fázi je vyvíjena deska s plošnými spoji. Všechny komponenty a procesor jsou namontovány. Žehlička je znovu sestavena a testována na přesnost teploty.

Klíčová slova: Teplota, PCB, LCD (displej z tekutých krystalů), senzor teploty, TRIAC (BT138), programování.

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1 INTRODUCTION

The electric iron has been a FMCG (fast moving consumer goods) product since the 1880s, but as is the case with many modern inventions, it has its roots in history. As early as 400 B.C. just like any technology or device the iron box (the modern-day word used to describe a device that is to use to accomplish one task, it was called by different names and with different designs/variants throughout ages and cultures) has faced many many iterations and many design changes to what we see today.

Let us consider the evolution and design changes throughout history

- Sad iron
- Box (slug) iron
- Smoothing iron with removable handle
- Charcoal iron
- Charcoal iron with chimney
- Gas smoothing
- Petrol iron
- 1930s electrical flatiron
- 1960s clothes iron
- 1990s Electric steam iron
- Modern wireless iron
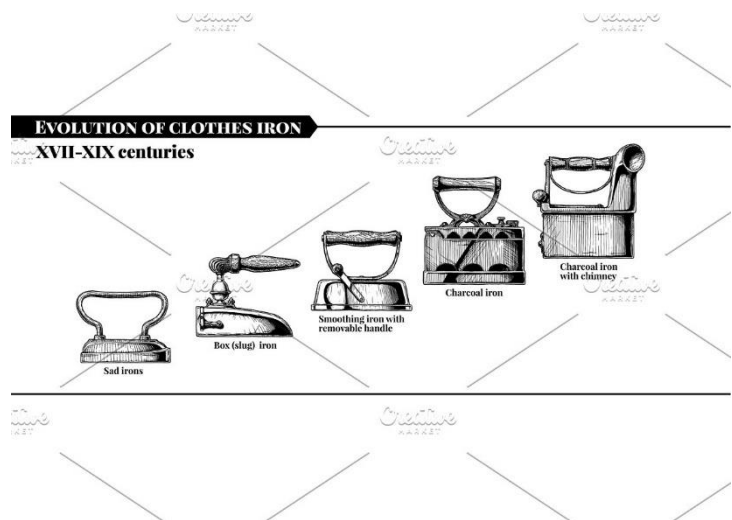
fig: 1evolution of iron box during ancient times
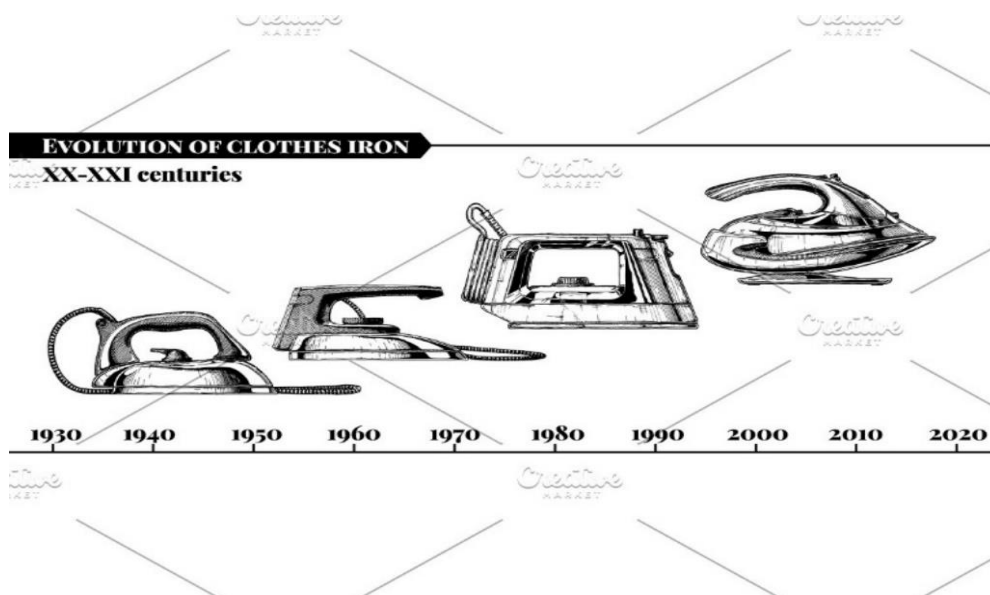
fig: 2 evolution of iron box in modern history

from the above examples there is one thing common. The final task is the same, what truly changes are the procedure or technology or method to accomplish it. One needs to rethink the solution, The method of executing it.

The iron box has had its journey of evolution. With today's modern technology almost all the products are more digitalised, attaining a better control, less failures and even lesser human intervention. Iron box without today's technology it is considered to be primitive. The future is digital iron box. The iron box is completely accomplished by microprocessor. The power is supplied or shut down precisely at predetermined temperature. Not much deviation ever occurs for a continued period of time.

1.1 Research aim and Methodology

The aim of this research work is to completely control the iron box digitally, this is achieved by first understanding all the parts and it's corresponding working principle and deciding all the parts that will be replaced or heavily edited. Select all the parts that will   Replace old components. After this decision is made the dimensional analysis of the iron box is carefully is performed. Select the placement of each and every individual component. In the process overcome all the complications and limitations like, comfortable safety with operating temperature of selected components, attempt to provide insulation or apply any form of adhesive or binding agents to isolate the electrical circuits from high temperatures. Design and produce a printed circuit board (PCB) and mount all the components and verify it's safe testing. The functionality of individual components and claims in the data sheet made by the manufacturer, Complete functionality of the iron box is verified.

1.2 Pricing of iron box

All research, all efforts, all innovation, all ideas are of no good use if it cannot be   profitably mass produced and sold, ultimately for the betterment of all humanity. Thus, pricing aspect is the most important to be considered before commencement.

fig: 3 Positioning chart of current electric iron research work

After through study of the different competitors in the market the fighting strategy is extremely varied and by different brands. Few companies are following 4P (Product, Price, Place, Promotion) method, 3M (Technical maturity, Market maturity, Competitive maturity) Etc.

To conclude, any product possesses a sweet spot between affordability and current market products price.

For evidences there already exists a product only in the USA market with some similar features and in certain aspects it is a little advanced, made by the manufacturer BLACK+DECKER for just 40$ USA dollars. Which exactly is within the price range of major current market players like Philips, Bosch etc.

1.3 replaceable parts

To accomplish this task a traditional iron box is first purchased. The following parts are replaced or heavily modified with different components. The function of this components has to be clearly understood so that it could be replicated when it is completely digitalized.

1.3.1 Thermostat
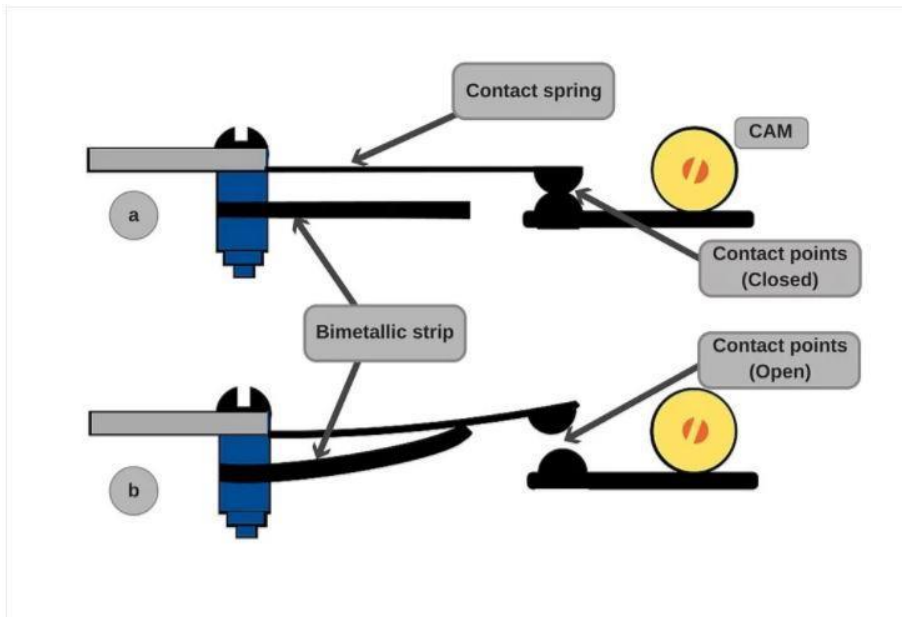
fig: 4Thermistor A: under normal temperature B: when iron becomes too hot

Thermostat utilizes a bimetallic strip to govern the switching that is connected in series with the resistance or heating detail.

The bimetallic strip is a component which converts a temperature variation into mechanical movement. A bimetallic strip includes two extraordinary metals fortified together. The 2 metals possess a different coefficient of expansion. If any such strip is heated, it starts to curl in the direction of the metal having the lower coefficient of expansion. Upon cooling, it straightens out and comes again to the normal function.

The principal reason of the bimetallic strip is:

The bimetallic strip is attached to a contact spring through, minute pins. The contact point between the strip and contact factors stays closed. during a surplus temperature variation, the unfamiliar enlargement causes the strip to twist and the touch among strip and make contact with spring opens. Consequently, the delivery to the heating element is momentarily paused (till the temperature goes all the way down to a pre-set value primarily based on the cloth selected). A tool stated to as the cam is located close to the contact spring, with which we specify the quantity of curving of bimetallic strip required to separate the touching.

As a consequence, the use of the bimetallic strip, the temperature is stored steady within sure limits.

The connecting elements, (that determines the degree of bending and straighten) between the knob and the thermistor is also removed.[1]

1.3.2 Capacitor

The thermostat permits in maintain the temperature within certain boundaries. But regular making and breaking of circuit harm the touch points and it can additionally bring about interference with radio reception. To keep away from this, a capacitor of a certain variety is connected across the 2 touch points. (In our model of iron box, we didn't have this component.) [1]

1.4 Selecting the Right Temperature for Ironing various Fabrics

One of the crucial things you should learn earlier than ironing clothes is the ideal temperature applying for the sort of fabric. Deciding on the perfect temperature on an iron could spell the difference amongst ease and catastrophe. The proper temperature choice will make ironing easier, faster and deliver greater professional outcomes. The incorrect temperature can mean extra paintings or, at worst, a burn wide hole that can't be repaired.

Thankfully, one of the features on maximum irons is a sliding scale that indicates the ideal temperature setting for specific sorts of material. As a reference, this chart makes use of a scale of 1 to5 -1 being coldest, five being hottest.[2]

1.5 How to Manage the Temperature of Your Iron

Unless you're simply pressing a solitary article of clothing, isolate your apparel by way of form of texture earlier than you start. Start by pressing the matters that require the most diminished temperature – acetate, nylon - then pass to silks, polyester, and different engineered textures. At long final, press cotton and linen fabric textures.

On the off threat which you must alternate lower back to a decrease press temperature, provide your iron no less than five minutes to sit back off before using. You'll be happy you did it.

If all else fails approximately what temperature to make use of, start low and iron on the incorrect side of the texture with a squeezing fabric. You could certainly flow the temperature up progressively to avoid burning. Burn imprints can be hard to expel but no longer usually incomprehensible if got early and while they're mild.[2]

1.5.1 selected temperatures for ironing different fabrics in ˚C

Type	Fabric	Temperature
Category 1	Linen	215^0
Category 2	Triacetate	200^0
	Cotton	204^0
Category 3	Viscose/rayon	190^0
Category 4	Wool	148^0
	Polyester	148^0
	Silk	148^0
Category 5	Acetate	135^0
	Acrylic	135^0
	Lycra/Spandex	135^0
	Nylon	135^0

Table 1 Temperature setting of major fabrics used for ironing of clothes[2]

2 Introduction to automatic control systems

- Control system - A control system is an interconnection of components forming a system configuration that will provide a desired system response. The basis for analysis of a system is the foundation provided by linear system, which assumes a cause effect relationship for the components of a system

Think of control around you-

Room temperature (heating from heaters (in cold countries) use air conditioners or cooling fans in warmer countries)

Automotive applications (traction control, RPM control, seat controls etc.)

Process–The device, plant, or system under control. The input and output relationship represent the cause -and-effect relationship of the process.

- What is automatic control?

Not manual, without any human intervention. Once started it has to sustain and take all the corrective measures by itself and proceed to accomplish desired target.

The need of automatic controls

Convenient (room temperature, remote operation for television, air conditioner etc).

Safety protection (automatic shut-off due to overheat, explosives detection/removal harmful gases).[3]

2.1 Differential equations of dynamic system

Transfer function, poles and zeros

Suppose there are linear, continuous-time-invariant systems with lumped parameters that are described by the differential equation 1.

$$y(n)+a_{n-1}y(n-1) +\cdots+a_1y(1) +a_0y = b_mu(m)+\cdots b_1u(1) +b_0u,\ \text{for}\ m\leq n \quad (1\text{-}1)$$

If **all initial conditions are set to zero** and the Laplace transformation is implied to both sides of the above equation, we obtain the following algebraic equation:

$$Y(s)(s^n+a_{n-1}s^{n-1}+\cdots+a_1s+a_0) =(b_ms^m+\cdots b_1s+b_0)\ U(s) \quad (1\text{-}2)$$

The transfer function is

$$F(s) = \frac{B(s)}{A(s)} = \frac{b_m s^m + \cdots b_1 s + b_0}{s^n + a_{n-1}s^{n-1} + \cdots + a_1 s + a_0} = \frac{Y(s)}{U(s)} \quad (1\text{-}6)$$
$$\rightarrow Y(s) = F(s) \cdot U(s)$$

where $A(s)$ and $B(s)$ describe the numerator and denominator polynomials, respectively. The roots of $A(s)=0$ are called the **system poles,** the roots of $B(s)=0$ are called the **system zeros.**

Let consider the transfer function of the system $F(s)=\dfrac{B(s)}{A(s)}$

- A system $F(s)$ is strictly proper if $F(j\omega)\rightarrow0$ as $\omega\rightarrow\infty$.

- A system $F(s)$ is semi-proper if $F(j\omega) \to D \neq 0$ as $\omega \to \infty$.
- A system $F(s)$ which is strictly proper or semi-proper is proper.
- A system $F(s)$ is improper if $F(j\omega) \to \infty$ as $\omega \to \infty$.

A proper system is physically realizable and can be described by a state-space description.

- If $m<n$ we say the model is strictly proper.
- If $m=n$ we say the model is semi-proper.
- If $m \leq n$ we say that the model is proper.

The transfer function of a continuous time system is a rational transfer function and can have numerous definitions.

The **transfer function** is the ratio of the Laplace transform of the output to the Laplace transform of input with zero as its initial condition.

<div align="center">OR</div>

The **transfer function** is the Laplace transform of the unit pulse function.[3]

2.2 Transfer function
Transfer function with real poles and zeros

A rational transfer function can be described as a ratio in **factored zero-pole** form

$$F(s) = \frac{b_m(s - s_{B1})(s - s_{B2}) \dots (s - s_{Bm})}{s^r a_n(s - s_1)(s - s_2) \dots (s - s_n)}$$

Transfer function with real poles in the **Bode Form** is

$$F(s) = K \frac{(1 + sT_{B1})(1 + sT_{B2}) \dots (1 + sT_{Bm})}{s^r(1 + sT_1)(1 + sT_2) \dots (1 + sT_n)}$$

where $T_i = \dfrac{1}{s_i}$ is **time constant of system**, $K = \dfrac{bo}{ao}$ is **gain**.

s_i = root of the polynomial.

Transfer function with complex pole and zero.

If we consider a dynamic system with complex pole and zero, then the transfer function in Bode form[3]

$$F(s) = K \frac{(1 + sT_{B1})(1 + sT_{B2}) \dots (1 + sT_{Bm})[(sT_B)^2 + 2\xi sT_B + 1]}{s^r(1 + sT_1)(1 + sT_2) \dots (1 + sT_n)[(s\tau)^2 + 2\xi s\tau + 1]}$$

3 Feedback control system

3.1 Open-loop Systems

A generic open-loop is shown in Fig. 3-1. It consists of a subsystem called an input transducer that coverts the form of the input to that used by the controller. The controller drives the process or plant. The input $w_* = w_*(t)$ is sometimes called the reference while the output can be called the controlled variable $y = y(t)$. The input $d = d(t)$ is called the disturbance. The controller output $u = u(t)$ is called the manipulated variable.[3]

w ... Desired value

w^* ... Input or Reference variable

u ... Manipulated input/Controller

y ... Output or Controlled variable

d ... Disturbance

y_S ... Not measured output

x_A ... Criteria variables
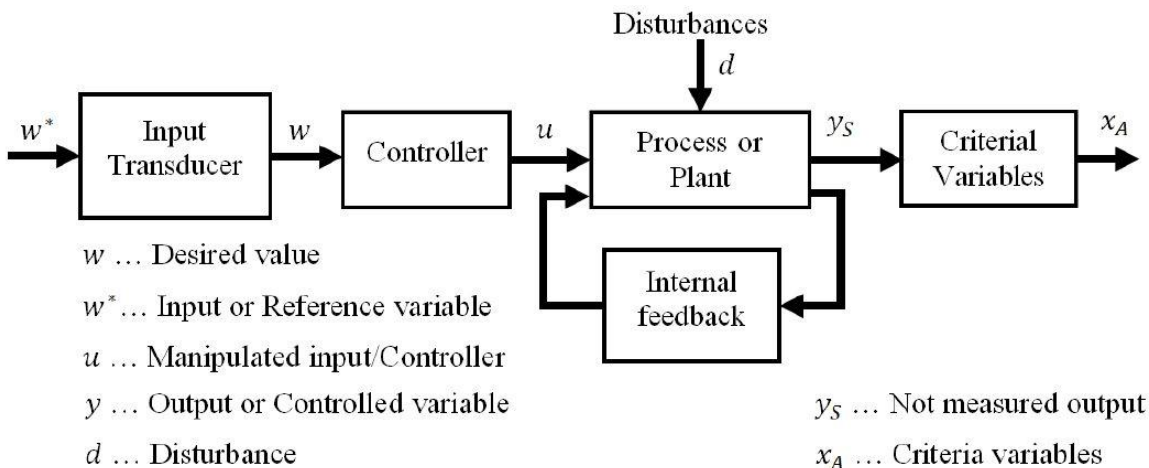
fig: 5 open loop control system

3.2 Closed-loop (Feedback Control) Systems

The generic architecture of a closed-loop system is shown in Fig. 1-19. The input transducer converts the form of the input w_* to the form used by the controller. An output transducer, or sensor, measures the output response and converts it into the form used by the controller. The summing junction algebraically adds the signal from the input w to the signal from the output y, which arrives via the feedback path, the return path from the output to the summing junction. [3]

w ... Desired value/set point

w^* ... Reference variable

y ... Controlled variable

u ... Manipulated input/ Controller output

y_S ... Not measured output

x_A ... Criteria variables

fig: 6 Closed loop control

4 Control of dynamic error

4.1 PID and PSD controllers

As a feedback controller, it delivers the control output at desired levels. Before microprocessors were invented, PID control was implemented by the analogue electronic components. But today all PID controllers are processed by the microprocessors. **Programmable logic controllers** also have the inbuilt PID controller instructions. Due to the flexibility and reliability of the PID controllers, these are traditionally used in process control applications.
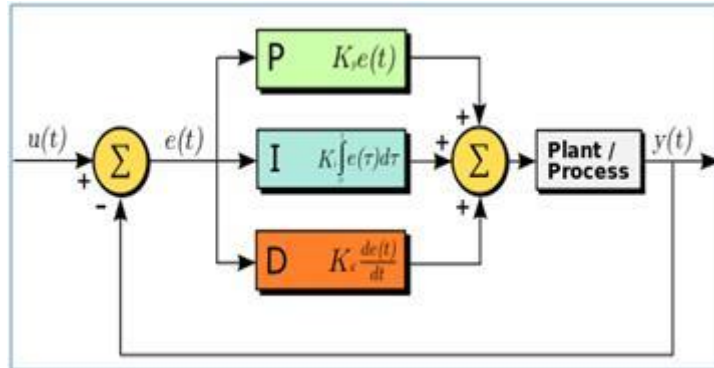
fig: 7 PID block diagram

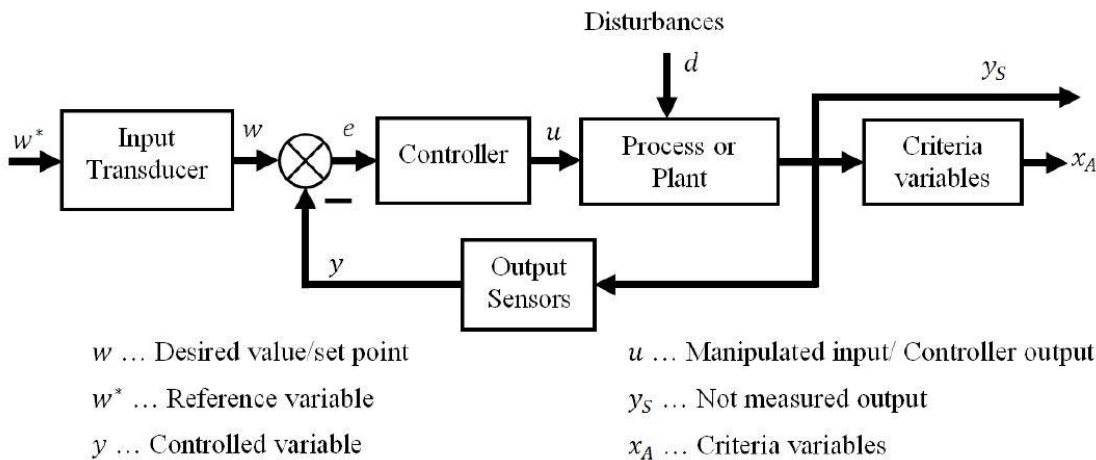With the use of low cost simple ON-OFF controller only two control states are possible, like fully ON or fully OFF. It is used for limited control application where these two control states are enough for control objective. However oscillating nature of this control limits its usage and hence it is being replaced by PID controllers.[4]

PID controller maintains the output such that there is zero error between process variable and set point/ desired output by closed loop operations. PID uses three basic control behaviours that are explained below.

4.2 P- Controller
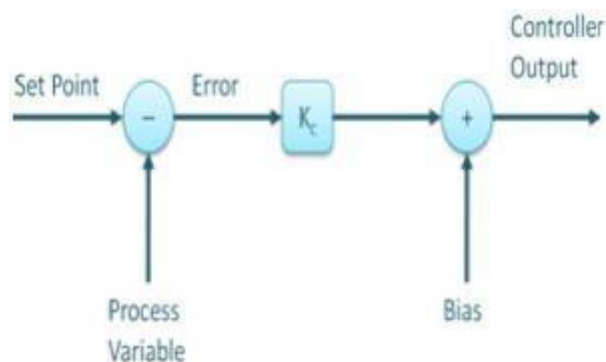
fig: 8 P-controller

Proportional or P- controller gives output which is proportional to current error e (t). It compares desired or set point with actual value or feedback process value. The resulting error is multiplied with proportional constant to get the output. If the error value is zero, then this controller output is zero.
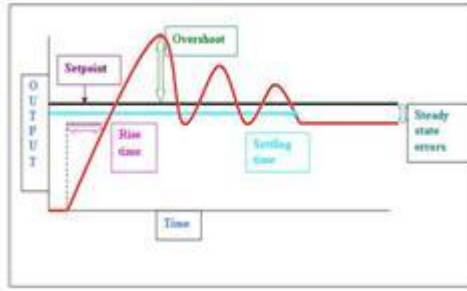
fig: 9 P-Controller Response

This controller requires biasing or manual reset when used alone. This is because it never reaches the steady state condition. It provides stable operation but always maintains the steady state error. Speed of the response is increased when the proportional constant Kc increases.

P controller = proportional only controller. The output from a P controller is proportional to the error and is equal to

$$uP(t)=P \cdot e(t)$$

where P represents the proportional gain, $e(t)$ represents the error.

Transfer function of P controller is

$$R_P(s) = \frac{U_P(s)}{E(s)} = P$$

The proportional mode is simple, provides an adjustment of the manipulated variable, does not provide zero offset although it reduces the error, speeds the dynamic response, and can cause instability if tuned improperly.[4]

4.3 I-Controller
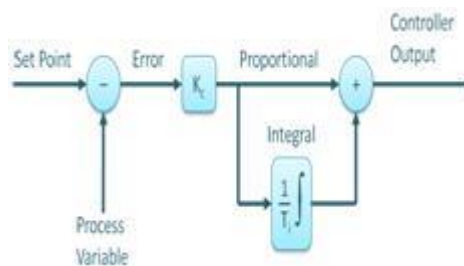
fig: 10 PI controller

Due to limitation of p-controller where there always exists an offset between the process variable and set point, I-controller is needed, which provides necessary action to eliminate the steady state error. It integrates the error over a period of time until error value reaches to zero. It holds the value to final control device at which error becomes zero.

Integral control decreases its output when negative error takes place. It limits the speed of response and affects stability of the system. Speed of the response is increased by decreasing integral gain Ki.
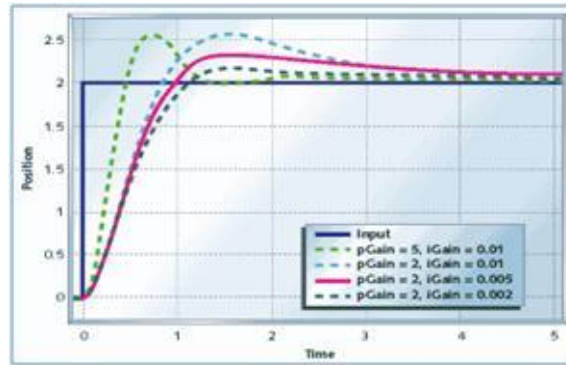
fig: 11 PI Controller Response

In above figure, as the gain of the I-controller decreases, steady state error also goes on decreasing. For most of the cases, PI controller is used particularly where high speed response is not required.

While using the PI controller, I-controller output is limited to somewhat range to overcome the **integral wind up** conditions where integral output goes on increasing even at zero error state, due to nonlinearities in the plant.[4]

Integral mode

$$u_I(t) = \frac{K_R}{T_I} \cdot \int_0^t e(\tau)d\tau + e(0)$$

where there is e (0) an initial condition.

The **integral mode** is simple; achieves zero offset; adjusts the manipulated variable in a slower manner than the proportional mode, thus giving poor dynamic performance; and can cause instability if tuned improperly

4.4 PI controller

PI controller = proportional-integral controller. A PI controller has two factors (terms) and two tuning parameters, one proportional to the error and the other proportional to the integral of the error. The PI controller output is equal t

$$u_{PI}(t) = P \cdot e(t) + I \cdot \int_0^t e(\tau)d\tau = K_R \left[e(t) + \frac{1}{T_I} \cdot \int_0^t e(\tau)d\tau \right]$$

where P represents proportional gain, I represents integral gain, K_R represents all controller gain, T_I represents the integral time, $e(t)$ is the error.

The PI controller transfer function is

$$R_{PI}(s) = \frac{U_{PI}(s)}{E(s)} = P + \frac{I}{s} = \frac{Ps + I}{s} = K_R \cdot \frac{T_I s + 1}{T_I s}$$

Integral mode

$$u_I(t) = \frac{K_R}{T_I} \cdot \int_0^t e(\tau)d\tau + e(0)$$

4.5 D-Controller

I-controller doesn't have the capability to predict the future behaviour of error. So, it reacts normally once the set point is changed. D-controller overcomes this problem by anticipating future behaviour of the error. Its output depends on rate of change of error with respect to time, multiplied by derivative constant. It gives the kick start for the output thereby increasing system response. [4]

The **derivative mode** is simple; does not influence the final steady state-value of error; provides rapid correction based on the rate of change of the controlled variable; but can cause undesirable high-frequency variation in the manipulated variable.
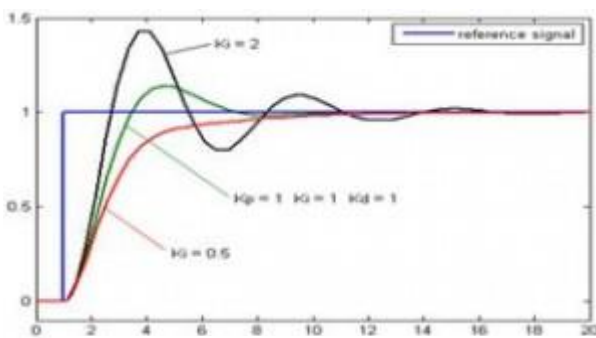
4.6 PID controller

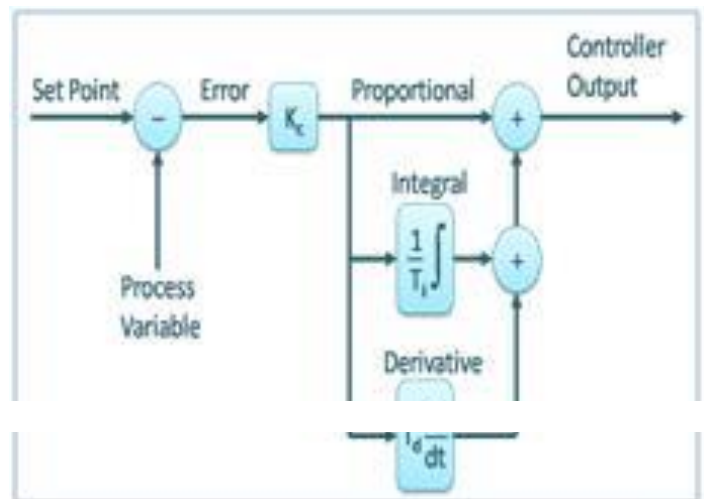
fig: 12 PID Controller Response

fig: 13   PID controller

In the above figure response of D controller is more, compared to PI controller and also settling time of output is decreased. It improves the stability of system by compensating phase lag caused by I-controller. Increasing the derivative gain increases speed of response.[4]

The PID controller output

$$u_{PID}(t) = P \cdot e(t) + I \cdot \int_0^t e(\tau)d\tau + D \cdot \frac{de(t)}{dt}$$

where P is the proportional gain, I is the integral gain, D represents the derivative gain.

Often the output is written in the follow form[5]

$$u_{PID}(t) = K_R \cdot \left[e(t) + \frac{1}{T_I} \cdot \int_0^t e(\tau)d\tau + T_D \cdot \frac{de(t)}{dt} \right]$$

where K_R is all controller gain, T_I is the integral time, T_D is the derivative time, $e(t)$ is the error.

A transfer function of a PID controller

$$R_{PID}(s) = \frac{U_{PID}(s)}{E(s)} = P + \frac{I}{s} + Ds = \frac{Ds^2 + Ps + I}{s}$$
$$= K_R \cdot \frac{T_D T_I s^2 + T_I s + 1}{T_I s}$$

The ideal PID algorithm is not physically realizable, that means no technical instrument can take perfect derivative. In this case the real PID controller has the following transfer function[5]

$$R_{PID}(s) = \frac{U_{PID}(s)}{E(s)} = P + \frac{I}{s} + \frac{Ds}{\frac{1}{N}s + 1} = K_R \cdot \left(\frac{T_I s + 1}{T_I s} + \frac{T_D s}{T_F s + 1} \right)$$

The derivative mode is important if the error is zero or very small but in spite of that the disturbances already begin to affect the controlled variable (the derivative is already present). In this situation, the error and integral error are nearly zero, but a substantial change in the manipulated variable would seem to be appropriate because the rate of change of the controlled variable is large. This situation is addressed by the derivative mode.

4.7 PSD controller

developing new analogue controller to control simple systems is not reasonable in financial or time issue. Due to this reason building a simple, discrete controller and implement its algorithm into single chip eight-bit microcontroller (MCU). This discrete controller - PSD - is characteristic its simplicity and variability. It can control plenty of less complicated systems by a mere change of its characteristic parameters. Thanks to modern approach is possible to create a full-featured controller including power action element on an area equal to 7cm2.

PSD – Proportional – Summation – Differentiation – controllers are discrete versions of regular analogue controllers. In this case, is function of controller commit to a MICROCHIP's single chip microcontroller. It is a simple, 8-bit MCU with an analogue input and PWM output. According to wide-spread usage PSD in common life and also in industry, this company has many types of specialized MCUs with integrated native PSD support. Classic PID controller working at continuous time area is using to set-up its own parameters next equation.

$$u_{(t)} = k_{(p)} \cdot e_{(t)} + k_I T_s \sum_{\tau=0}^{t} e_\tau + k_D \frac{y_{(t)} - y(t - T_s)}{T_s}$$

- Proportional $k_{(p)}$

- Integral $k_{(I)}$

- Derivation $k_{(D)}$

- Ts is sample period

In case, the constant Ts going nears zero, $T_s \rightarrow 0$, the equation is quite similar to classic continuous controller equation. In a given case we using same methods of optimization and setting up particular parameters like in classic controllers.
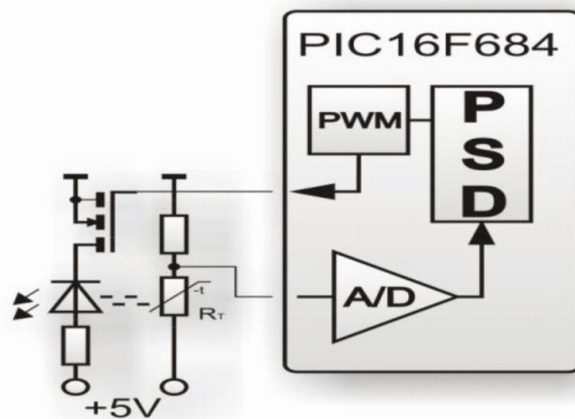
fig: 14 Block diagram of controller and system and PWM

5 Step response

The response of the system to any changes in input is known as the step response. The change of input is considered as 1 and the output is considered as 0. Identification of a system is necessary in order to plan corrective measures for making the overall system perform in a desirable manner. In general, identification of a system involves the determination of the parameters of the approximating model of the system. This may be done by exciting the system with a suitable input and studying the output of the system.

Based on the step response, it is easy to determine the gain, the time constant and the time delay.

6   XC 16 Compiler

6.1   Introduction

The MPLAB XC16 C compiler is defined and described in the following topics:

• Device Description

• Compiler Description and Documentation

• Compiler and Other Development Tools

6.2   Device description

The MPLAB XC16 C compiler fully supports all Microchip 16-bit devices:

• The dsPIC$^{®}$ family of digital signal controllers combine the high performance required in digital signal processor (DSP) applications with standard microcontroller (MCU) features needed for embedded applications.

• The PIC24 family of MCUs are identical to the dsPIC DSCs with the exception that they do not have the digital signal controller module or that subset of instructions. They are a subset and are high-performance MCUs intended for applications that do not require the power of the DSC capabilities.[6]

6.3   Compiler description and documentation

The MPLAB XC16 C compiler is a full-featured, optimizing compiler that translates standard ANSI C programs into 16-bit device assembly language source. The compiler also supports many command-line options and language extensions that allow full access to the 16-bit device hardware capabilities and affords fine control of the compiler code generator.

The compiler is a port of the GNU Compiler Collection (GCC) compiler from the Free

Software Foundation.

The compiler is available for several popular operating systems, including 32 and 64-bit

Windows$^{®}$, Linux and Apple OS X.

The compiler can run in one of three operating modes: Free, Standard or PRO. The Standard and PRO operating modes are licensed modes and require an activation key and Internet connectivity to enable them. Free mode is available for unlicensed customers. The basic compiler operation, supported devices and available memory are identical across all modes. The modes only differ in the level of optimization employed by the compiler

This key feature of the compiler is discussed in the following sections.[6]

6.3.1   ANSI C Standard

The compiler is a fully validated compiler that conforms to the ANSI C standard as defined by the ANSI specification (ANSI x3.159-1989) and described in Kernighan and Ritchie's *The C Programming Language* (second edition). The ANSI standard includes extensions to the original C definition that are now standard features of the language. These extensions enhance portability and offer increased capability. In addition, language extensions for dsPIC DSC embedded-control applications are included.

6.3.2   ANSI Standard Library Support

The compiler is distributed with a complete ANSI C standard library. All library functions have been validated and conform to the ANSI C library standard. The library includes functions for string manipulation, dynamic memory allocation, data conversion, time- keeping and math functions (trigonometric, exponential and hyperbolic). The standard I/O functions for file handling are also included, and, as distributed, they support full access to the host file system using the command-line simulator. The fully functional source code for the low-level file I/O functions is provided in the compiler distribution and may be used as a starting point for applications that require this capability.[6]

6.3.3   Attributes and Qualifiers

The compiler keyword _ _attribute_ _allows you to specify special attributes of variables, structure fields or functions. This keyword is followed by an attribute specification inside double parentheses, as in:

int last_mode _ _attribute_ _ ((persistent));

In other compilers, qualifiers are used to create qualified types:

persistent int last_mode;

Generally speaking, qualifiers indicate how an object should be accessed, whereas attributes indicate where objects are to be located. Attributes also have many other purposes.[6]

7 Different apparatus used

7.1 PIC controller

Over recent decades, microcontrollers have evolved to be low cost, intense problem-solving gadgets that even mechanical engineers will use in constructing tailor-made instrumentation for their test studies centres. Run of the mill undertakings contain checking of analogue signal, detective pulses and giving timing signals. Obviously, these items need to be possible with a sophisticated computer connected with the help of USB to commercial data acquisition and signal processing system but there are many varied instances within which the small, microcontroller, requiring just multiple milliamps of power performs out the assignment splendidly and at low-cost.

Current microcontrollers provide extremely one-of-a-kind dedicated device peripherals, all internal a solitary chip. One needs to produce small degree of supporting appliance to control the chip and interface its fringe gadgets to the symptoms of intrigue and, while powered up, those gadgets have to be compelled to be organized and discovered by victimization the acceptable computer code program.[6]

7.2 PIC24FV16KM202 family

General Purpose, 16-Bit Flash Microcontroller with XLP Technology

7.2.1 Analog Peripheral Features

• Up to Two 8-Bit Digital-to-Analog Converters
(DAC):
- Soft Reset disable function allows DAC to retain its output value through non-VDD Resets
- Support for Idle mode
- Support for left and right-justified input data
• Two Operational Amplifiers (Op Amps):
- Differential inputs
- Selectable power/speed levels:
- Low power/low speed
- High power/high speed
• Up to 22-Channel, 10/12-Bit Analog-to-Digital Converter:
- 100k samples/second at 12-bit conversion rate (single Sample-and-Hold)
- Auto-scan with Threshold Detect
- Can operate during Sleep
- Dedicated band gap reference and temperature sensor input
• Up to Three Rail-to-Rail Analog Comparators:
- Programmable reference voltage for comparators
- Band gap reference input
- Flexible input multiplexing
- Low-power or high-speed selection options
• Charge Time Measurement Unit (CTMU):
- Capacitive measurement, up to 22 channels
- Time measurement down to 200 ps resolution
- Up to 16 external Trigger pairs
• Internal Temperature Sensor with Dedicated A/D Converter Input

7.2.2 Special Microcontroller Features

- Wide Operating Voltage Range Options:
- 1.8V to 3.6V (PIC24F devices)
- 2.0V to 5.0V (PIC24FV devices)
- Selectable Power Management modes:
- Idle: CPU shuts down, allowing for significant power reduction
- Sleep: CPU and peripherals shut down for substantial power reduction and fast wake-up
- Retention Sleep mode: PIC24FV devices can enter Sleep mode, employing the
retention regulator, further reducing power consumption
- Doze: CPU can run at a lower frequency than peripherals, a user-programmable feature
- Alternate Clock modes allow on-the-fly switching to a lower clock speed for selective power reduction
- Fail-Safe Clock Monitor:
- Detects clock failure and switches to on-chip, low-power RC oscillator
- Ultra Low-Power Wake-up Pin Provides an
External Trigger for Wake from Sleep
- 10,000 Erase/Write Cycle Endurance Flash
Program Memory, Typical
- 100,000 Erase/Write Cycle Endurance
Data EEPROM, Typical
- Flash and Data EEPROM Data Retention: 20 Years
Minimum
- Self-Programmable under Software Control
- Power-on Reset (POR), Power-up Timer (PWRT)
and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its Own On-Chip
RC Oscillator for Reliable Operation
- On-Chip Regulator for 5V Operation
- Selectable Windowed WDT Feature
- Selectable Oscillator Options including:
- 4x Phase Locked Loop (PLL)

- 8 MHz (FRC) Internal RC Oscillator:
- HS/EC, high-speed crystal/resonator

oscillator or external clock
- In-Circuit Serial Programming™ (ICSP™) and
In-Circuit Emulation (ICE) – via Two Pins

- In-Circuit Debugging
- Programmable High/Low-Voltage
Detect (HLVD) module
- Programmable Brown-out Reset (BOR):
- Software enable feature
- Configurable shutdown in Sleep
- Auto-configures power mode and sensitivity based on device operating speed
- LPBOR available for re-arming of the POR [6]

7.2.3 High-Performance RISC CPU

- Modified Harvard Architecture
- Operating Speed:
- DC – 32 MHz clock input

- 16 MIPS at 32 MHz clock input
• 8 MHz Internal Oscillator:
- 4x PLL option
- Multiple clock divide options
- Fast start-up
• 17-Bit x 17-Bit Single-Cycle Hardware
Fractional/Integer Multiplier
• 32-Bit by 16-Bit Hardware Divider
• 16 x 16-Bit Working Register Array
• C Compiler Optimized Instruction Set Architecture
• 24-Bit-Wide Instructions
• 16-Bit-Wide Data Path
• Linear Program Memory Addressing, up to
6 Mbytes
• Linear Data Memory Addressing, up to 64 Kbytes
• Two Address Generation Units (AGUs) for Separate
Read and Write Addressing of Data Memory[6]

7.2.4 CPU core block diagram of PIC24 family

fig: 15 CPU Core Block Diagram of PIC24 Family[6]
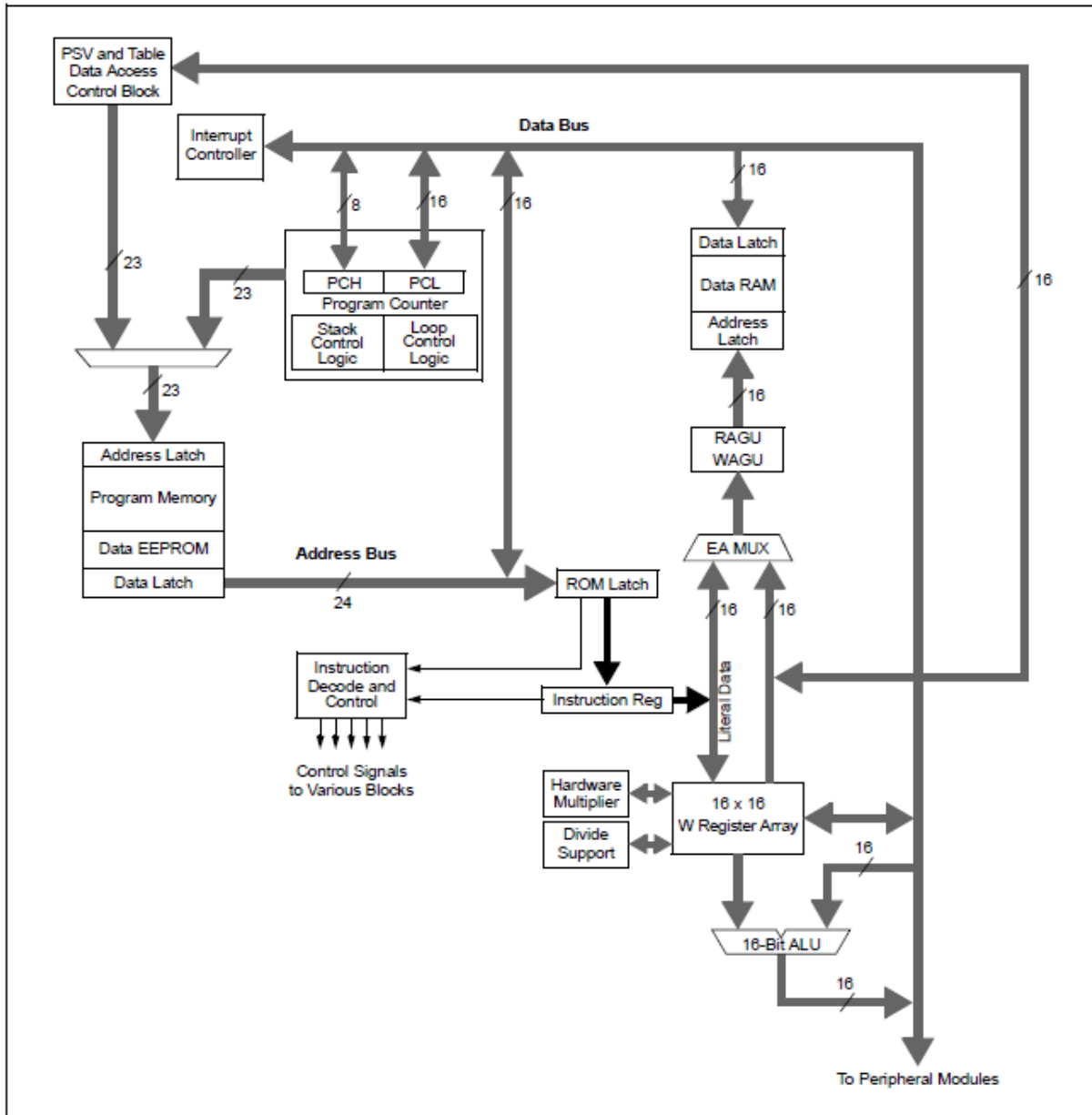
Register(s) Name	Description
W0 through W15	Working Register Array
PC	23-Bit Program Counter
SR	ALU STATUS Register
SPLIM	Stack Pointer Limit Value Register
TBLPAG	Table Memory Page Address Register
PSVPAG	Program Space Visibility Page Address Register
RCOUNT	Repeat Loop Counter Register
CORCON	CPU Control Register

7.2.5 28 pin diagram OF PIC24 family

28-Pin SPDIP/SSOP/SOIC

```
              MCLR/RA5 ┤1      28├ AVDD
                  RA0 ┤2      27├ AVss
                  RA1 ┤3      26├ RB15
                  RB0 ┤4      25├ RB14
                  RB1 ┤5      24├ RB13
                  RB2 ┤6      23├ RB12
                  RB3 ┤7      22├ RB11
                  Vss ┤8      21├ RB10
                  RA2 ┤9      20├ RA6 or VDDCORE
                  RA3 ┤10     19├ RA7
                  RB4 ┤11     18├ RB9
                  RA4 ┤12     17├ RB8
                  VDD ┤13     16├ RB7
                  RB5 ┤14     15├ RB6
          (PIC24F16KMX02)
```
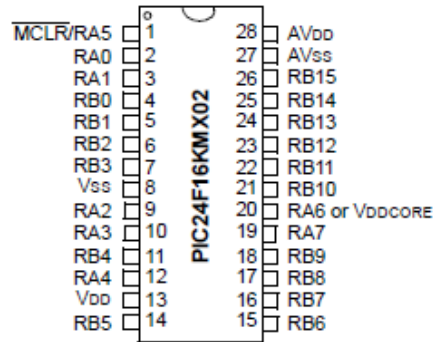
Pin	Pin Features	
	PIC24FXXKMX02	PIC24FVXXKMX02
1	MCLR/VPP/RA5	
2	CVREF+/VREF+/DAC1REF+/AN0/C3INC/CN2/RA0	
3	CVREF-/VREF-/AN1/CN3/RA1	CVREF-/VREF-/AN1/RA1
4	PGD1/AN2/CTCMP/ULPWU/C1IND/C2INB/C3IND/U2TX/CN4/RB0	
5	PGC1/OA1INA/OA2INA/AN3/C1INC/C2INA/U2RX/CTED12/CN5/RB1	
6	OA1INB/OA2INB/AN4/C1INB/C2IND/SDA2/U1RX/TCKIB/CTED13/CN6/RB2	
7	OA1OUT/AN5/C1INA/C2INC/SCL2/CN7/RB3	
8	Vss	
9	OSCI/CLKI/AN13/CN30/RA2	
10	OSCO/CLKO/AN14/CN29/RA3	
11	SOSCI/AN15/U2RTS/U2BCLK/CN1/RB4	
12	SOSCO/SCLKI/AN16/PWRLCLK/U2CTS/CN0/RA4	
13	VDD	
14	PGD3/AN17/ASDA1/SCK2/IC4/OC1E/CLCINA/CN27/RB5	
15	PGC3/AN18/ASCL1/SDO2/IC5/OC1F/CLCINB/CN24/RB6	
16	AN19/U1TX/INT0/CN23/RB7	AN19/U1TX/C2OUT/OC1A/INT0/CN23/RB7
17	AN20/SCL1/U1CTS/C3OUT/OC1B/CTED10/CN22/RB8	
18	AN21/SDA1/T1CK/U1RTS/U1BCLK/IC2/OC4/CLC1O/CTED4/CN21/RB9	
19	SDI2/IC1/OC5/CLC2O/CTED3/CN9/RA7	
20	C2OUT/OC1A/CTED1/INT2/CN8/RA6	VCAP OR VDDCORE
21	PGD2/SDI1/OC3A/OC1C/CTED11/CN16/RB10	
22	PGC2/SCK1/OC2A/CTED9/CN15/RB11	
23	DAC1OUT/AN12/HLVDIN/SS2/IC3/OC2B/CTED2/CN14/RB12	DAC1OUT/AN12/HLVDIN/SS2/IC3/OC2B/CTED2/INT2/CN14/RB12
24	OA1INC/OA2INC/AN11/SDO1/OCFB/OC3B/OC1D/CTPLS/CN13/RB13	
25	DAC2OUT/CVREF/OA1IND/OA2IND/AN10/C3INB/RTCC/C1OUT/OCFA/CTED5/INT1/CN12/RB14	
26	DAC2REF+/OA2OUT/AN9/C3INA/REFO/SS1/TCKIA/CTED6/CN11/RB15	
27	Vss/AVss	
28	VDD/AVDD	

fig: 16 Pin Diagram of PIC24 Family[6]

7.3 Opto coupler MOC 3023

The MOC3020 Series consists of gallium arsenide infrared emitting diodes, optically coupled to a silicon bilateral switch as shown in fig.

To order devices that are tested and marked per VDE 0884 requirements, the suffix" V" must be included at end of part number. VDE 0884 is a test option. They are designed for applications requiring isolated TRIAC triggering.
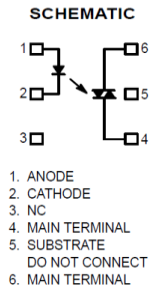
SCHEMATIC

1. ANODE
2. CATHODE
3. NC
4. MAIN TERMINAL
5. SUBSTRATE
   DO NOT CONNECT
6. MAIN TERMINAL

fig: 17 opto-isolator internal circuit

Recommended for 115/240 V_{ac}(rms) Applications:

Solenoid/Valve Controls
Static ac Power Switch
 Lamp Ballasts
 Solid State Relays
 Interfacing Microprocessors to 115 V_{ac} Peripherals
 Incandescent Lamp Dimmers
 Motor Controls

This opt isolator should not be used to drive a load directly. It is in- tended to be a trigger device only. Additional information on the use of optically coupled triac drivers is available in Application Note AN–780A.[7]

In this circuit the "hot" side of the line is switched and the load connected to the cold or ground side. The 39-ohm resistor and 0.01 F capacitor are for snubbing of the triac, and the 470-ohm resistor and 0.05 F capacitor are for snubbing the coupler. These components may or may not be necessary depending upon the particular Triac and Load used[7]
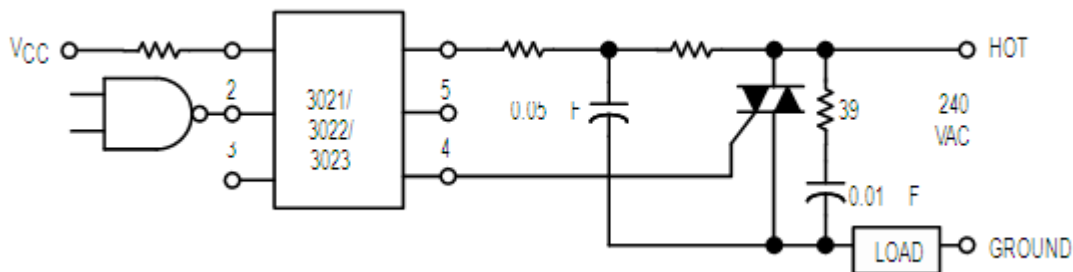
fig: 18 Application Circuit

7.4 Liquid crystal display (LCD)

A Liquid crystal display (LCD) is a low cost, low power device capable of displaying text and images. LCDs are extremely common in embedded systems, since such systems often do not have video monitors like those that come standard with desktop systems.

LCD is an electronically-modulated optical device shaped into a thin, flat panel made up of any number of color or monochrome pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector.

LCDs with a small number of segments, such as the one shown in the above figure, have individual electrical contacts for each segment. An external dedicated circuit supplies an electric charge to control each segment. This display structure is unwieldy for more than a few display elements.

The LCD controller provides a relatively simple interface between a processor and an LCD. LCDs can be added quite easily to an application and use as few as three digital output pins for control.
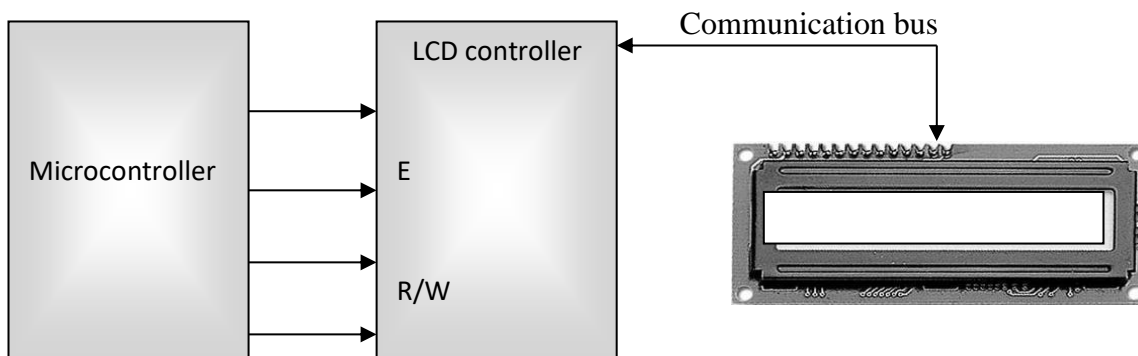

fig: 19 Schematic Diagram of LCD

There are different types of LCDs such as reflective LCD, absorption LCD, dot matrix LCD. Each type of LCD is able to display multiple characters. In addition, each character may be displayed in normal or inverted fashion. The LCD may permit a character to be blinking or may permit display of a cursor indicating the current character. Such functionality would be difficult to be implemented using software. Thus, an LCD controller is used to provide a simple interface to an LCD, perhaps eight data inputs and one enable input. [8]

This byte may be a control word, which can be an instruction or data word. The most common connector used for the 44780 based LCDs is 14 pins in a row, with pin centres 0.100" apart. The pins are wired as:

Pins	Description
1	Ground
2	V_{cc}
3	Contrast Voltage
4	"R/S" _Instruction/Register Select
5	"R/W" _Read/Write LCD Registers
6	"E" Clock
7-14	Data I/O Pins

Table 2 LCD Pin Description

Technical Specifications

- Display format   -   16 characters x 2 lines.
- Construction   -   TN/STN LCD panel, Bezel, Zebra and PCB.
- Optional Edge   -   Array LED or EL backlight.
- Controller   -   KS0066U or Equivalent.
- Power   -   5V single power input.
- Temperature   -   Normal / Custom available.

Above is the quite simple schematic. The LCD panel's *Enable* and *Register Select* is connected to the Control Port. The Control Port is an open collector / open drain output. While most Parallel Ports have internal pull-up resistors, there are few which don't. Therefore, by incorporating the two 10K external pull up resistors, the circuit is more portable for a wider range of computers, some of which may have no internal pull up resistors.[8]

In the above memory map, area up to 0F and 4F is the visible display. As one can see, it measures 16 characters per 2 lines. The numbers in each box in memory address that corresponds to that on screen. Thus the "Set Cursor Position" instruction 80h tells the LCD to position the cursor. Adding the cursor Position to 80h does these sets the cursor to the required position on the screen.

We make no effort to place the Data bus into reverse direction. Therefore, we hard wire the *R/W* line of the LCD panel, into write mode. This will cause no bus conflicts on the data lines. As a result, we cannot read back the LCD's internal Busy Flag which tells us if the LCD has accepted and finished

processing the last instruction. This problem is overcome by inserting known delays into our program. The 10k Potentiometer controls the contrast of the LCD panel.[8]

7.5 Resistor

A resistor is a two terminal electrical device designed to oppose the flow of electric current by producing a voltage drop between its terminals in proportion to the current, that is, it is governed by ohms law.

Resistors have extremely commonplace in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistive wire (wire made of a high-resistivity alloy, such as nickel/chrome). The primary characteristics of resistors are their resistance and the power they can dissipate. Other characteristics include temperature coefficient , noise, and inductance. Less well-known is critical resistance, the value below which power dissipation limits the maximum permitted current flow, and above which the limit is applied voltage. Critical resistance depends upon the materials constituting the resistor as well as its physical dimensions; it's determined by design.

Resistors can be integrated into hybrid printed circuits, and integrated circuits. Size, and position of leads (or terminals) are relevant to equipment designers; resistors must be physically large enough not to overheat when dissipating their power.

fig: 20 resistor

7.6 Thermistor specifications

Resistance: 100Kohm + / -1%
B value: 3950 + / -1%
Accuracy: + / -1%
Glass packaging: 2.0 + / -0.2mm
Lead length: 32 + / -5mm
Operating temperature range: -50 to +260C
Thermal time constant =10 – 17 s (in still air)

fig: 21 thermistor

Thermal dissipation constant =1.1 – 1.6mW / C
Insulation resistance 50M or over by DC500V megge (between glass and lead wire)

Measuring Temperature with an NTC Thermistor

Knowing the temperature in a project can a very useful piece of data to have handy. Knowledge of temperature can help regulate room temperature for a comfortable environment,

For this article, we are only concerned with one type of sensor that can measure temperature. This sensor is called a thermistor.

A thermistor exhibits resistance that is far more sensitive to temperature than that of other types of resistors. [9]

Theory

In a typical application of a resistor, you do not want the resistance to change with temperature. This is not really possible in real life but it's possible to ensure only a small change in resistance with a large change of temperature. If this were not the case, resistors would make weird things happen in circuits, such as an LED that gets much brighter and dimmer as the ambient temperature changes.

But, what if you really did want that LED's brightness to be a function of temperature? This is where the thermistor comes in. As you might have guessed, a thermistor has a large change in resistance with a small change of temperature. To illustrate this concept, check out a typical curve of a thermistor:
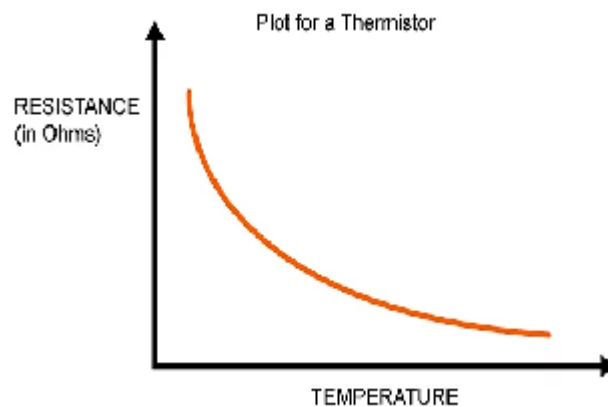

fig: 22 theoretical resistance verse temperature graph

The units are shown but not the actual values as a thermistor can tailor to different ranges depending on which you buy. As you can see, the temperature gets hotter, the resistance is lower. This is a property of a Negative Temperature Coefficient resistor (NTC for short).

There are also thermistors that have Positive Temperature Coefficient (PTC for short) which means as the temperature increases, the resistance increases. However, PTC thermistors have a sort of tipping point and greatly change the resistance at some temperature. This makes the PTC thermistor a little harder to interface with. For this reason, for most low-cost temperature measurement, NTC thermistors are preferred.
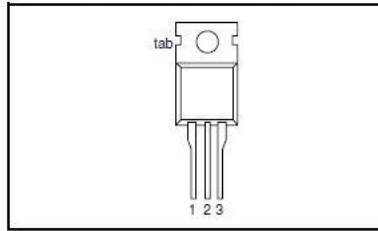
For the remainder of the article, you can assume we'll be referring to NTC type thermistors.

7.7 TRIAC BT138 (on / off switch)

PINNING - TO220AB

PIN	DESCRIPTION
1	main terminal 1
2	main terminal 2
3	gate
tab	main terminal 2

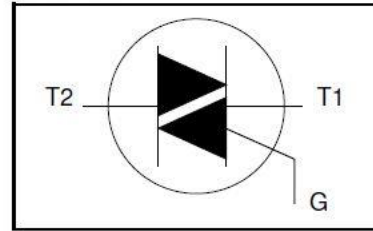**PIN CONFIGURATION**

tab

1 2 3

SYMBOL

T2 T1

G

fig: 23 TRIAC BT-138

Passivated TRIACs in a plastic envelope, intended for use in applications requiring high bidirectional transient and blocking voltage capability and high thermal cycling performance. Typical applications include motor control, industrial and domestic lighting, heating and static switching

TRIAC is similar to two back to back (anti parallel) connected thyristor but with only three terminals. The conduction of a TRIAC is initiated by injecting a current pulse into the gate terminal. The gate loses control over conduction once the TRIAC is turned on. The TRIAC turns off only when the current through the main terminals become zero. Therefore, a TRIAC can be categorized as a minority carrier, a bidirectional semi-controlled device[7]

8 Practical part

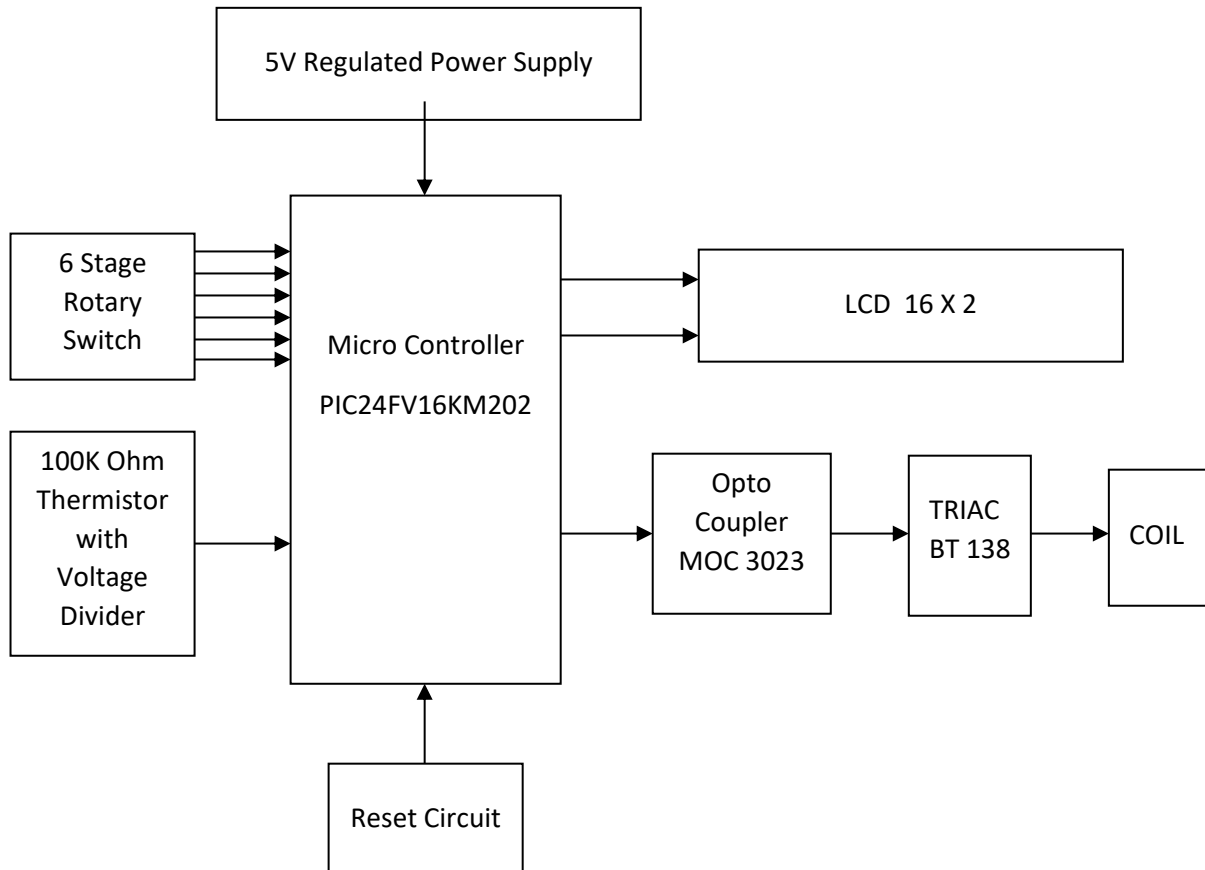## 8.1 Functional Block Diagram

fig: 24 Block diagram

Functional Description

In this project development we are using PIC Microcontroller, Regulated Power Supply, LCD, Rotary Switch, Heating Coil, Optocoupler, TRIAC, Resistor and Thermistor.

We used 16-bit PIC microcontroller for this project development. We used 10-bit ADC mode in this PIC controller for reading iron box temperature with the help of Temperature sensor and Voltage divider circuit. We used rotary switch to select the mode of fabric on which we need to iron. LCD is used to display the information of temperature and selected mode name for fabric. Optocoupler is used at the output of controller to control the coil of iron box through the TRIAC. Reset circuit is used to restart the process of controller whenever its get hang or malfunction.

8.2 Structural, dimensional analysis and choice of location for sensors and circuits in orpat oei 187

The selected iron box is completely disassembled and it is clearly witnessed at the first sight that it has a base plate upon which a plastic moulded cover is used to isolate the base plate from the upper part of the iron box. The resistance coil is integrated into the base plate in a 'U' shape which is optimally placed so that the entire base plate is heated uniformly to the pre-decided temperature of the fabric. The knob and other controls are isolated from the base plate the analogous control moving parts and thermistor are mounted on the base

plate. The extent of bending action is automatically pre-decided when the respective fabric is selected namely linen, cotton, wool, silk, nylon.

The temperature at various points across the base plate is measured and it is noted that the temperature of the base plate at the extreme corners are relatively lesser than the temperature measured near the coil. It is also observed that about two inches away from the central part of the coil the thickness of the base plate is higher and we concluded that we would drill a small hole of about 1 mm and place the thermistor at this point and give the necessary safety. two sleeves are used to separate the two leads of the thermistor and to mount the thermistor a temperature resistant sealant (up = to 350 ^{0} C) is used, and two wires are drawn from two respective leads of the thermistor and for these two wires a bigger sleeve is selected and the temperature resistant sealant is acting as an insulation and the Leeds of the thermistor is completely secured inside a bigger nylon sleeve (withstand up to 300 ℃).

The iron box cover is completely covered with the temperature insulation tape for thermal resistance. As a precaution electrical insulation tape is also used.

It is noted that from the data sheets of TRIAC (BT 138) and opto-isolator (MOC 3023) and the operating temperature is ranging from -40 to +85 ℃, and 125 ℃ respectively. These devices are mounted on the general purpose Printed Circuit Board (PCB) and this board is placed above the insulated cover plate (thermally and electrically) of the iron box.
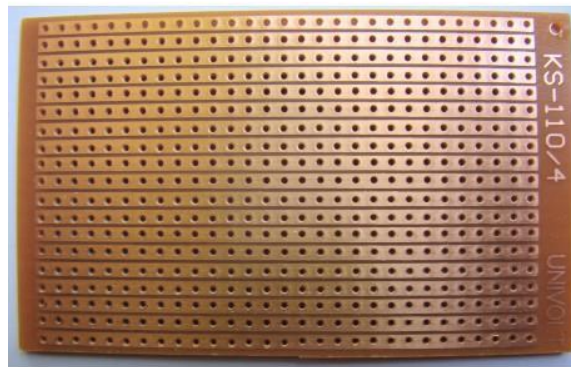

fig: 25 General purpose printed circuit board

From the datasheets of the PIC24FV16KM202, it is clear that the operating temperature is relatively low. So, the microprocessor and all the wires connecting from the microprocessor for LCD display, rotary switches, etc. is isolated and placed inside the handle bar of the iron box. No risk could be taken up with placement of the microprocessor on a single PCB and leave the entire circuit on the plastic mould cover. Which would result in failure of the entire circuit.
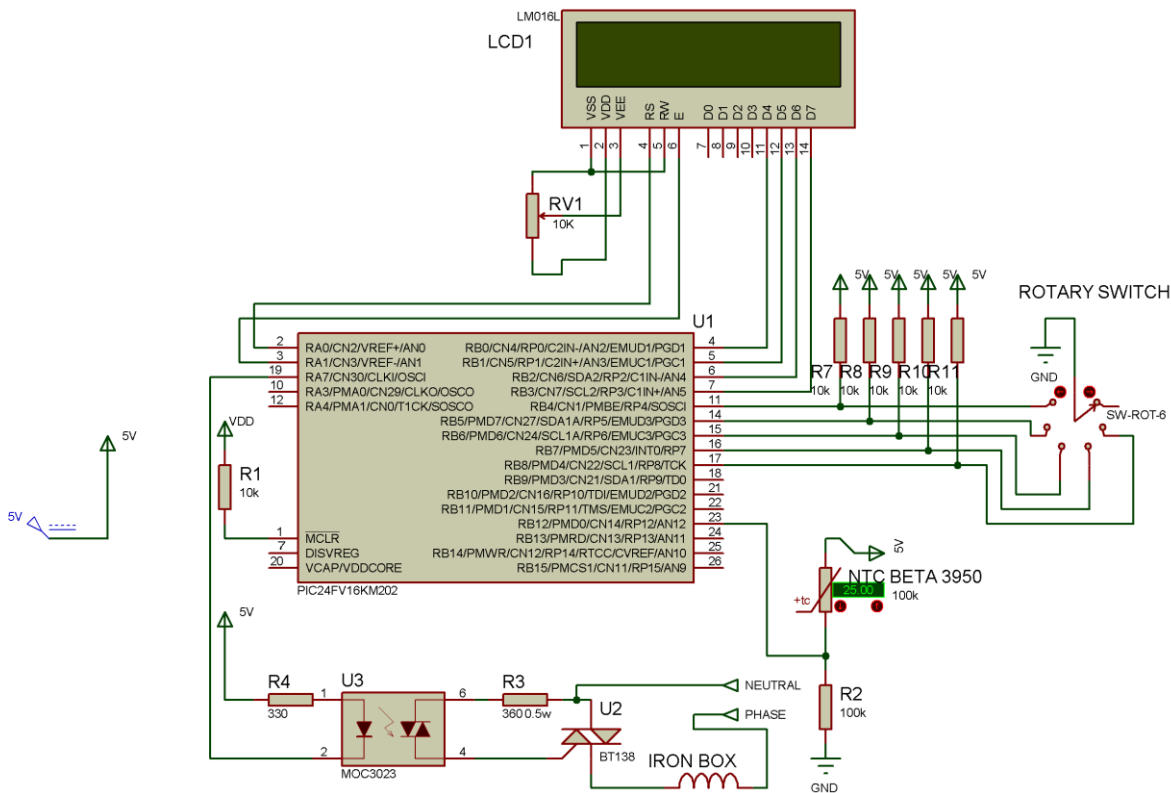
8.3 Circuit diagram of digital iron box

fig: 26 complete circuit diagram.

(Protheious 8.0 software is used to draw the circuit)

The data major data lines using devices are LCD display screen and the rotary switch the data lines from RB5-RB9 are used for rotary switch RB0 TO RB3. Optocoupler is used for opto isolation of the circuit with microprocessor, there is big voltage in the other side of circuit. It also enables or disables ON-OFF switch (TRIAC BT-138). The pull-up resistors of 10 kΩ are connected for switching and selecting different fabrics in the rotary switch.

8.3.1 Temperature measurement by voltage divider circuit
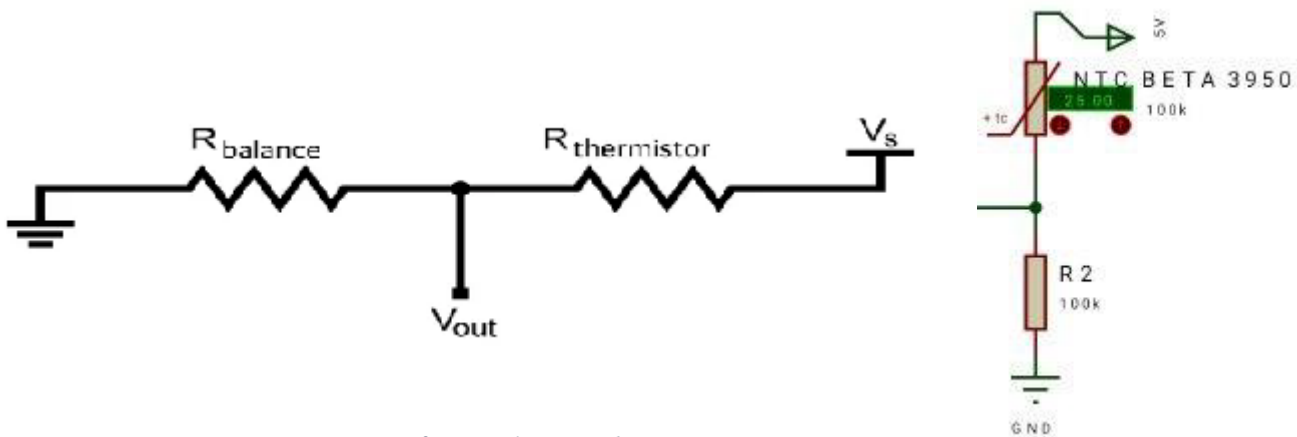
fig: 27 Voltage Divider Circuit

There are theoretically two resistors (100 kΩ) (Thermistor is also a resistor), but its resistance varies with the temperature which can be observed by the graph below since NTC type Thermistor is considered the relationship between the temperature and resistance is non- linear. When the surface is heated the resistance of the thermistor varies and this variation in resistance is converted to voltage variation.
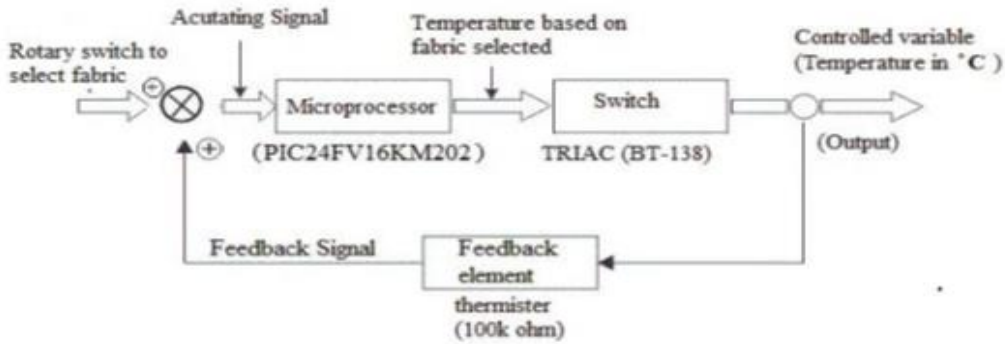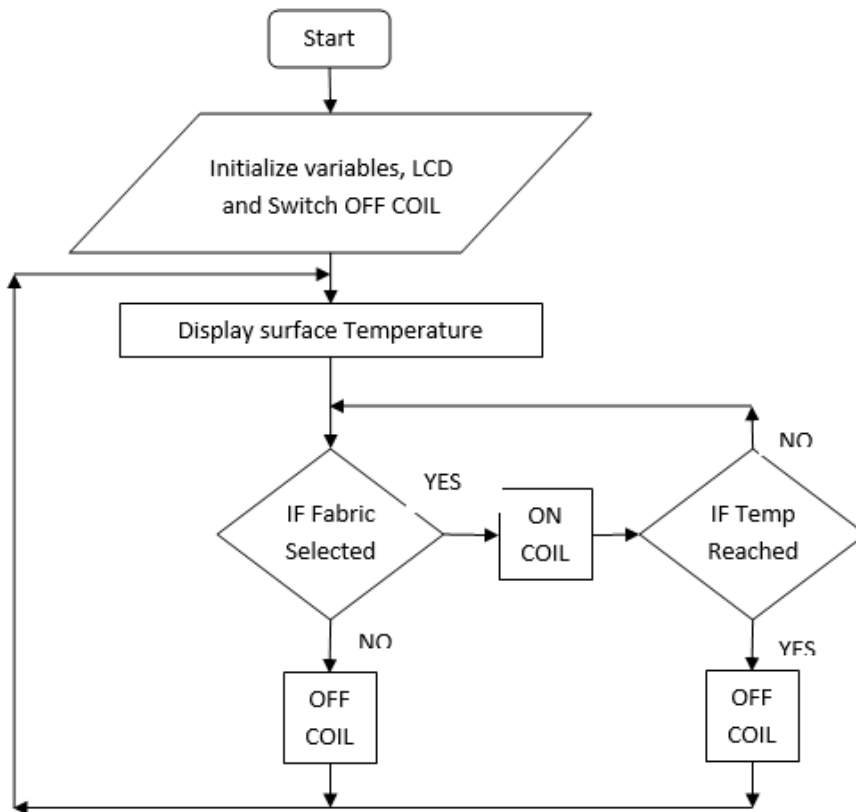
8.4 Flow Chart

fig: 28 Block diagram of the dynamic system (iron box)

fig: 29 Flow chart

Above figure shows the flow chart for the project program. Through which we can explain the working of the project flow.

When we switch on the Digital iron box it will initialize LCD, Sensor's and Display welcome message. After sensor is initialized it will read the iron box surface temperature (which is nothing but room

temperature) and display on LCD. Then it will be waiting for the fabric selection to start the working. Once when the user is selected the fabric by using the rotary switch, the rotary switch has five positions Iron box will heat the surface to defined temperature for the selected fabric and it keeps ON maintaining the temperature without considerable deviations unit the user sets the switch OFF. It won't allow iron Box temperature to exceed the limited temperature (a temperature fuse is installed in the iron box it has a limit of $250\,^0$ C). So, by which fabric life will be saved. Once the Rotary switch is Turned OFF then Coil of Iron Box will be OFF.

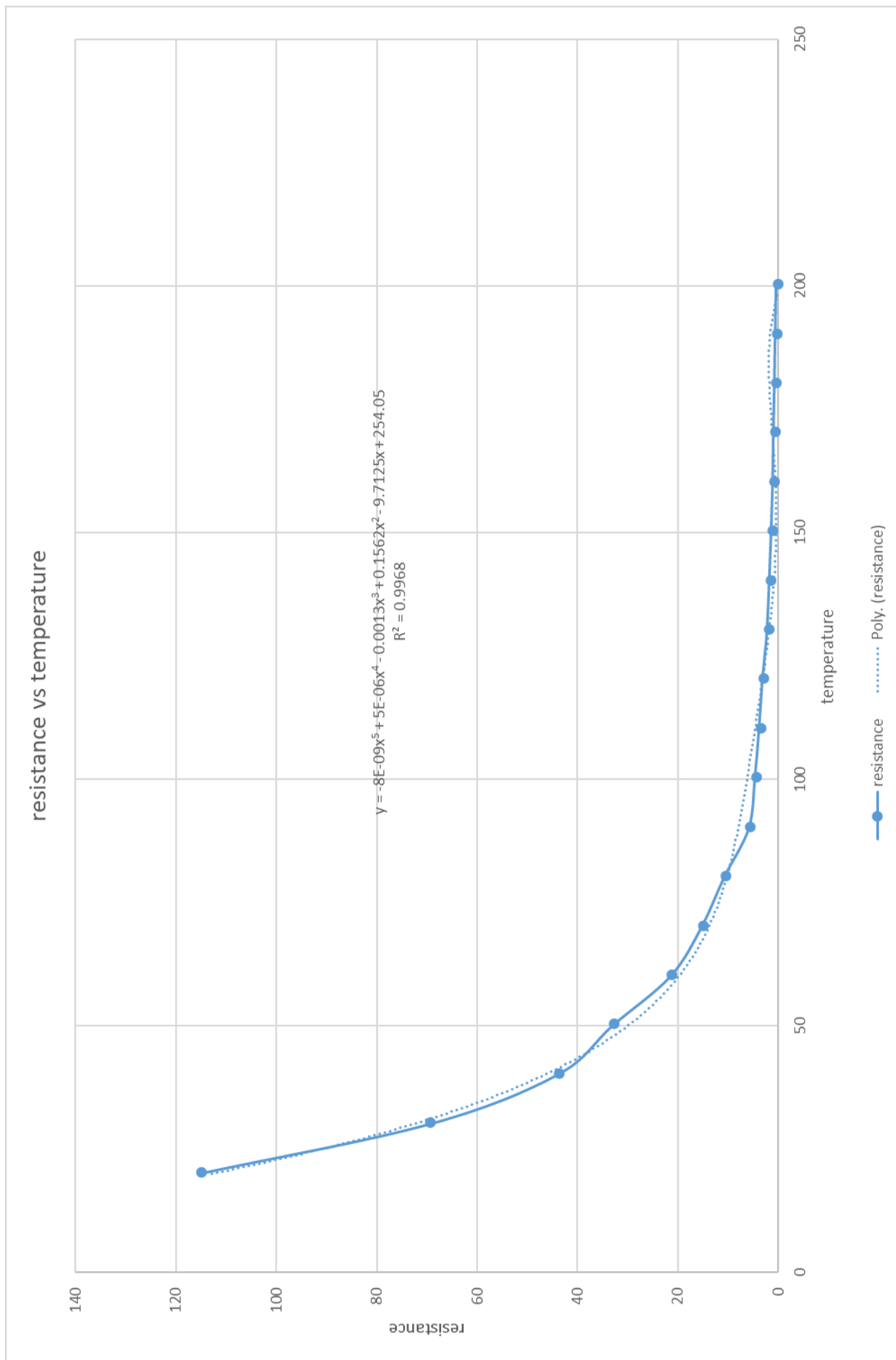## 8.5 Measurement of static characteristics

fig: 30 Temperature sensor

fig: 31 Evaluating the temperature of olive oil

fig: 33 Heating olive oil

fig: 32 multi meter

resistance vs temperature

$y = -8E-09x^5 + 5E-06x^4 - 0.0013x^3 + 0.1562x^2 - 9.7125x + 254.05$

$R^2 = 0.9968$

temperature

resistance

— resistance   ····· Poly. (resistance)

The manufacturer of the NTC type thermistor has provided the graph of resistance vs temperature. With a perfect exponential curve. The static characteristics of the graph is measured and the functionality is verified by the following procedure:

- Olive oil is selected as a heating liquid (measurement fluid).
- The oil is heated up to 200 ^{0}C and the temperature is constantly verified by placing the temperature senor in the oil.
- For a time interval of every 10 ^{0}C the temperature is measured and the resistance at temperature from 200 to room temperature is measured.
- For minimizing the error three sets of reading is taken and the mean value of the reading is used to plot the graph

As it is witnessed from the graph that the regression value (similarity between graph obtained from plotting the values and the exponential curve) is 99.68 %.

8.6 Approximation of equations

```
Rt = 100*(5-y)./y;
T = -8e-9* Rt.^5 + 5e-6*Rt.^4 - 0.0013*Rt.^3 + 0.1562*Rt.^2 - 9.7125*Rt +
254.05;

x = fminsearch( 'krit_up_folipd', [0.1,0.1] );
K = x(1)
T1 = x(2)

hi = step( tf( [K], [T1 1 0] ), t1 );

subplot(4,1,3)
plot(t1,h1,t1,hi)
grid on
xlabel('t [s]');
ylabel('h [°C]');


function out = krit_up_folipd(x)

    global h1;
    global t1;

    K = x(1);
    T = x(2);
    e = h1 - step( tf( [K],[T 1 0] ), t1 );

    out = sum( e.*e );
```

K =

  0.1593

T1 =

  3.3540

   After measuring the static characteristics form the curve, the above program is written in the MATLAB software to obtain the K (static gain of the system) and T_i (time constant of the system) values. These values form the basis for further progress in the project functionality verification.

   Approximation values of k and T_i obtained from the MATLAB software.
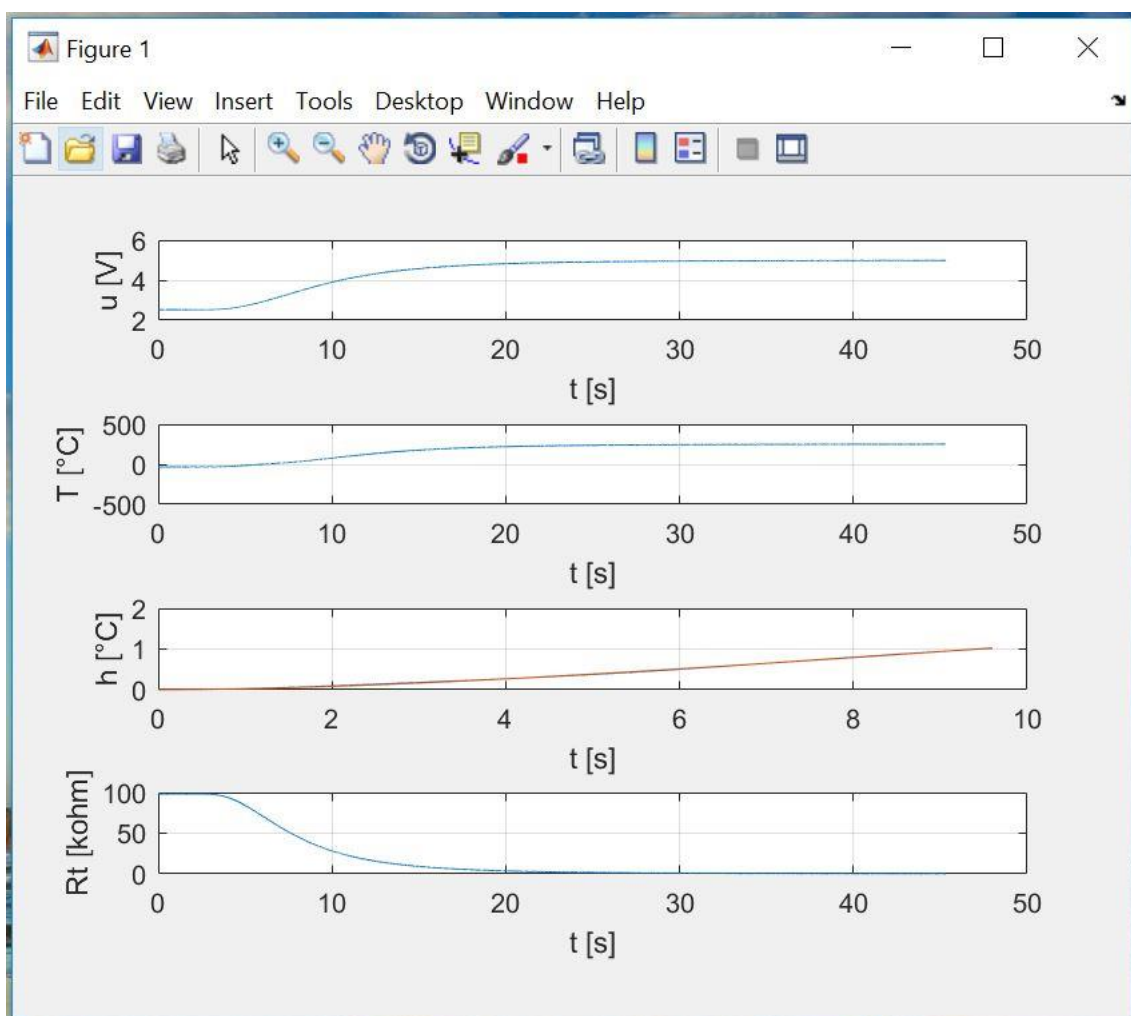
8.7 Step response of iron box

fig: 34 Step response

recalculated values form the step voltage in the below figure. Blue line indicates from simulation and the red line is the data from measurement which was recalculated from step response.
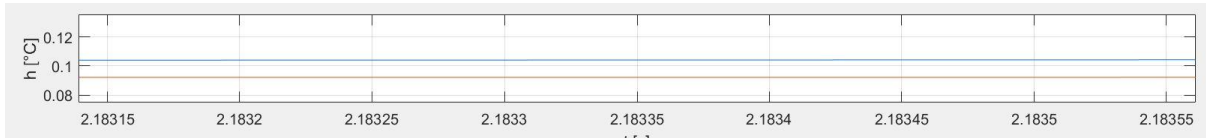
fig: 35 Detailed view of h (^{0}C) verses t (s)

u(V) verses t (s) is the voltage graph.

T(^{0}C) verses t (s) is the temperature variation with time graph.

R_t (in kΩ) verses t (s) is the variation of temperature of thermistor with change in time. The resistance of the thermistor is almost 0 when subject to higher temperatures.

$$u_{eff} = \frac{u}{\sqrt{2}} \quad \frac{220}{\sqrt{2}} = 162.63V$$

$$y = \frac{u}{u\ eff}$$

$$Rt = 100 * \frac{5-y}{y}$$

$$T = -8e9 * Rt^5 + 5e - 6 * Rt^4 - 0.0013 * Rt^3 + 0.1562 * Rt^2 - 9.7125 * Rt + 254.05$$

8.8 Scheme of the dynamic system (iron box) in Simulink software
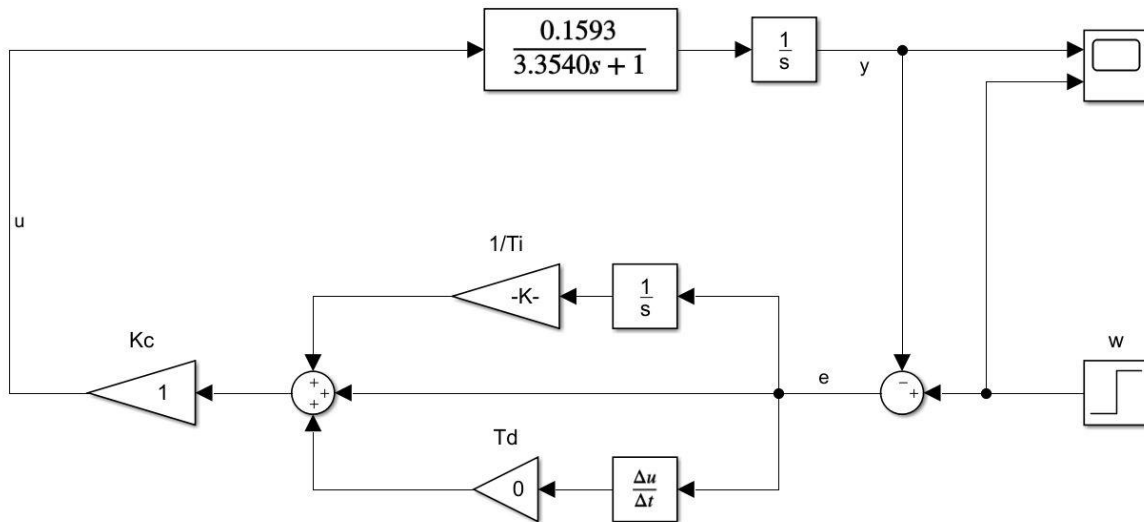

fig: 36 scheme of the iron box in Simulink software.

The above scheme is plotted in the Simulink software. The iron box is replicated. For simulation purposes the values are changed at will, all the methods of PI paraments are set in the above scheme.

8.9 Setting of PID parameters by different methods and relevant equations

8.9.1 Setting parameters by experimental method (by hand)

K= 0.2
T_i= 500
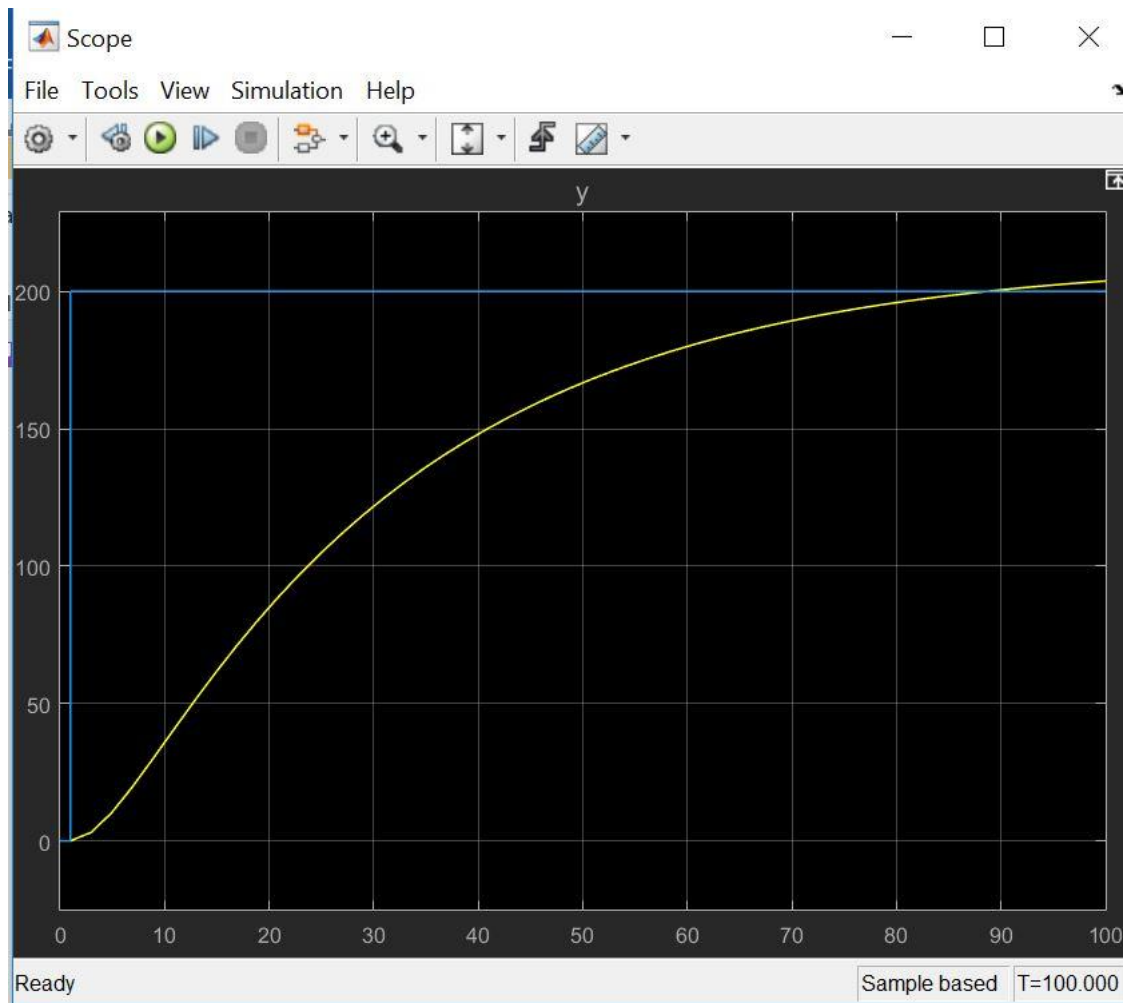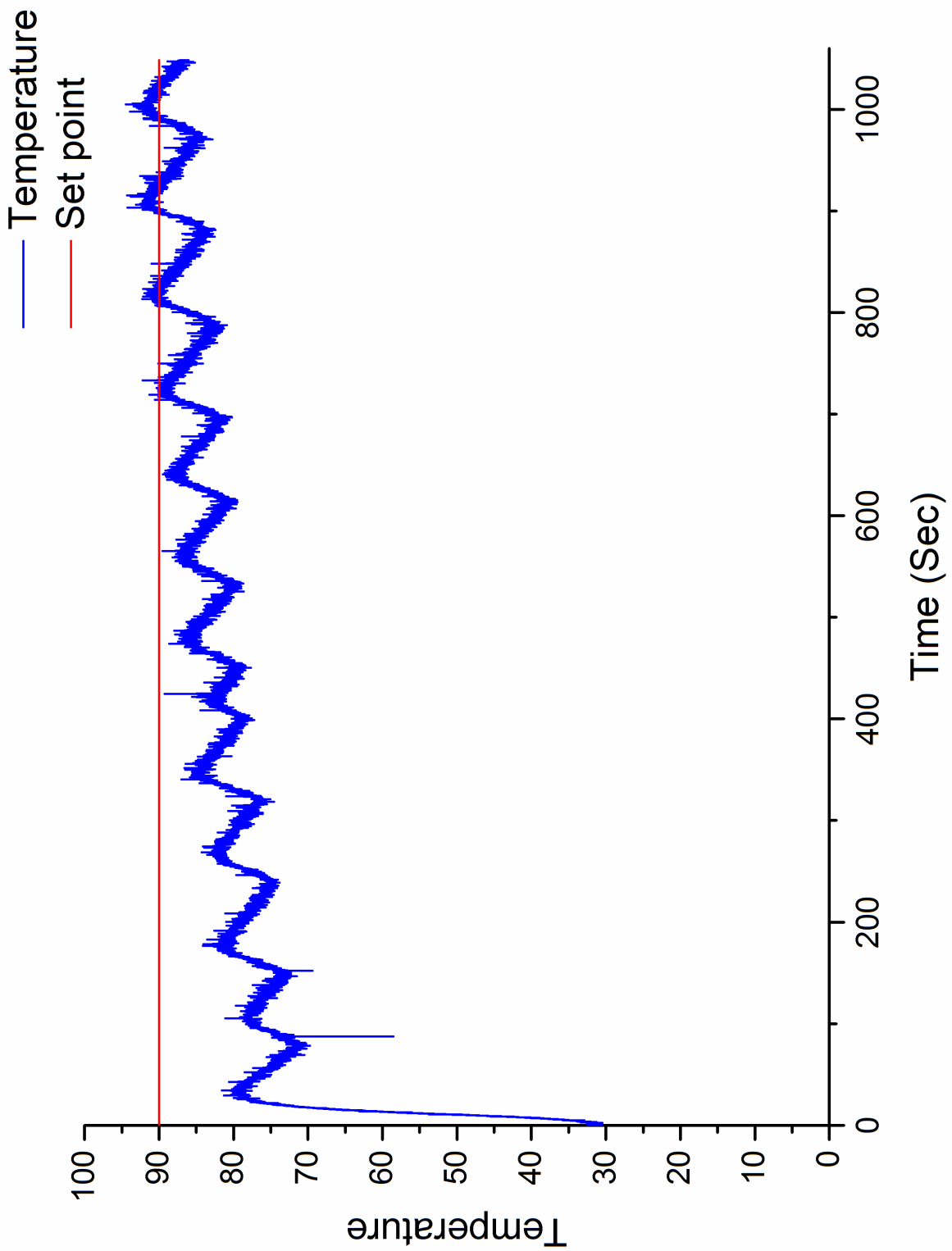T_s =0.1 (on PIC24FV16KM202)

fig: 37 Simulative results from experimental method

      The values of K, T_I and T_S values are given as input parameters to Simulink software and the iron box circuit. The simulative results and the results from actual iron box testing are plotted. This is the most suitable method to obtain the values of PI parameters.

graph: experimental method

8.9.2 Method of optimal module

Proportional controller

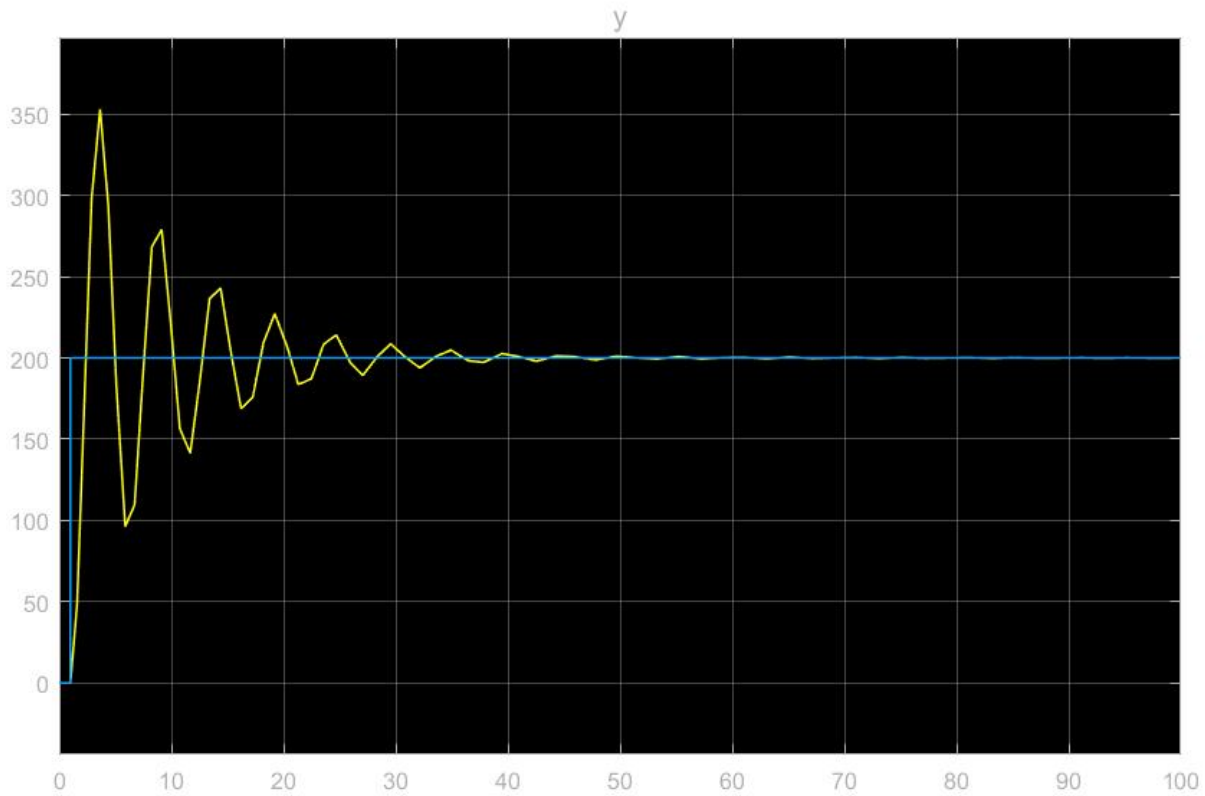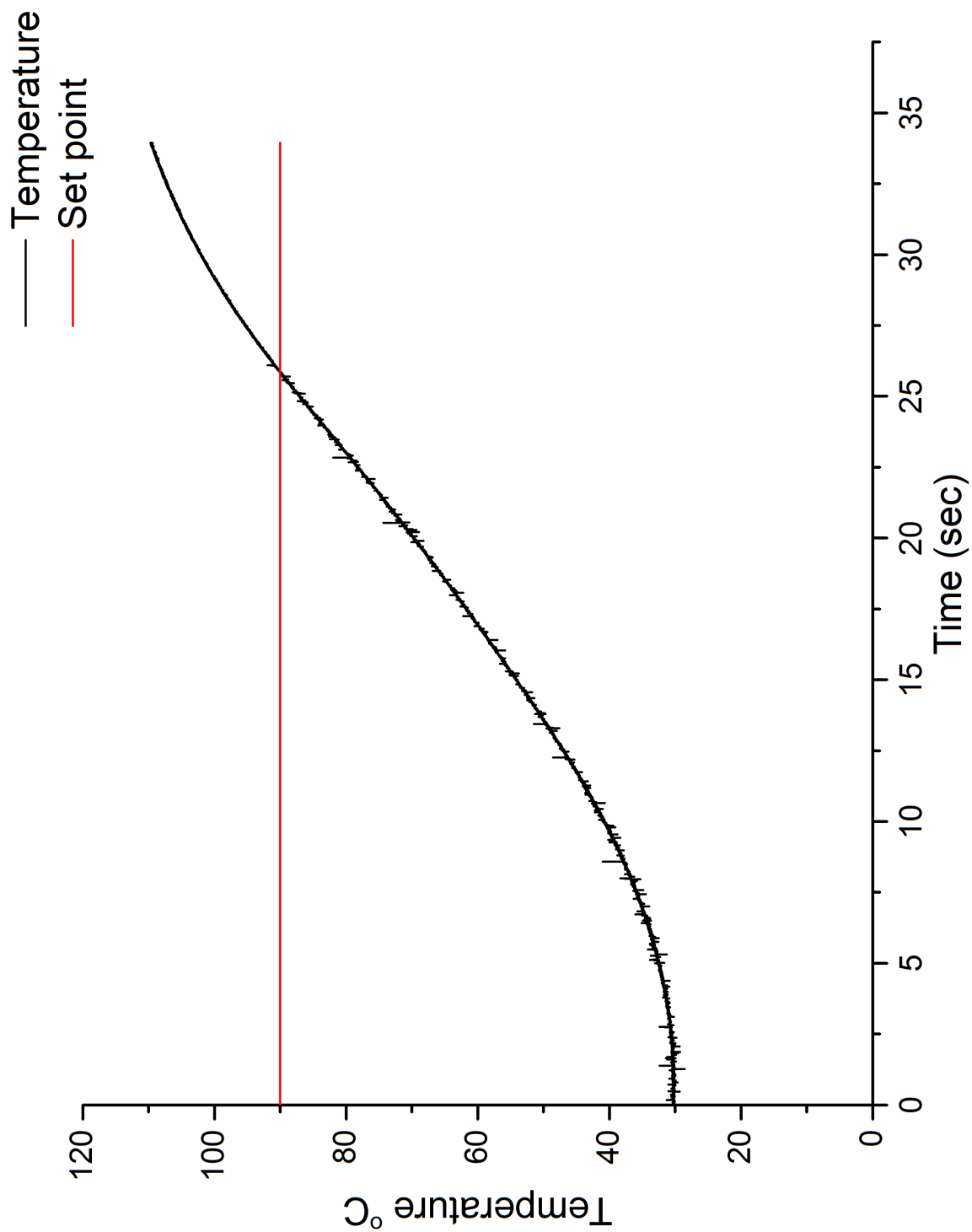$$K_c = \frac{1}{2KT} \rightarrow 31.3873$$

T_i = very big value

fig: 38 Simulative results from optimal modulus method

From the results from K_c it is clear that it is a very big value, and this method is not the suitable method for calculation of PI parameters. The over shoot of the temperature is very high it could result in the destruction of iron box.

Graph: optimal module

8.9.3 Symmetrical optimum method (most suitable method)

K= 0.1593   system parameters

T= 3.3540   system parameters

T_s =0.1   PIC Microcontroller sample period

$$K_c = \frac{4}{k(8.T + 3.Ts)} \rightarrow 0.92547$$
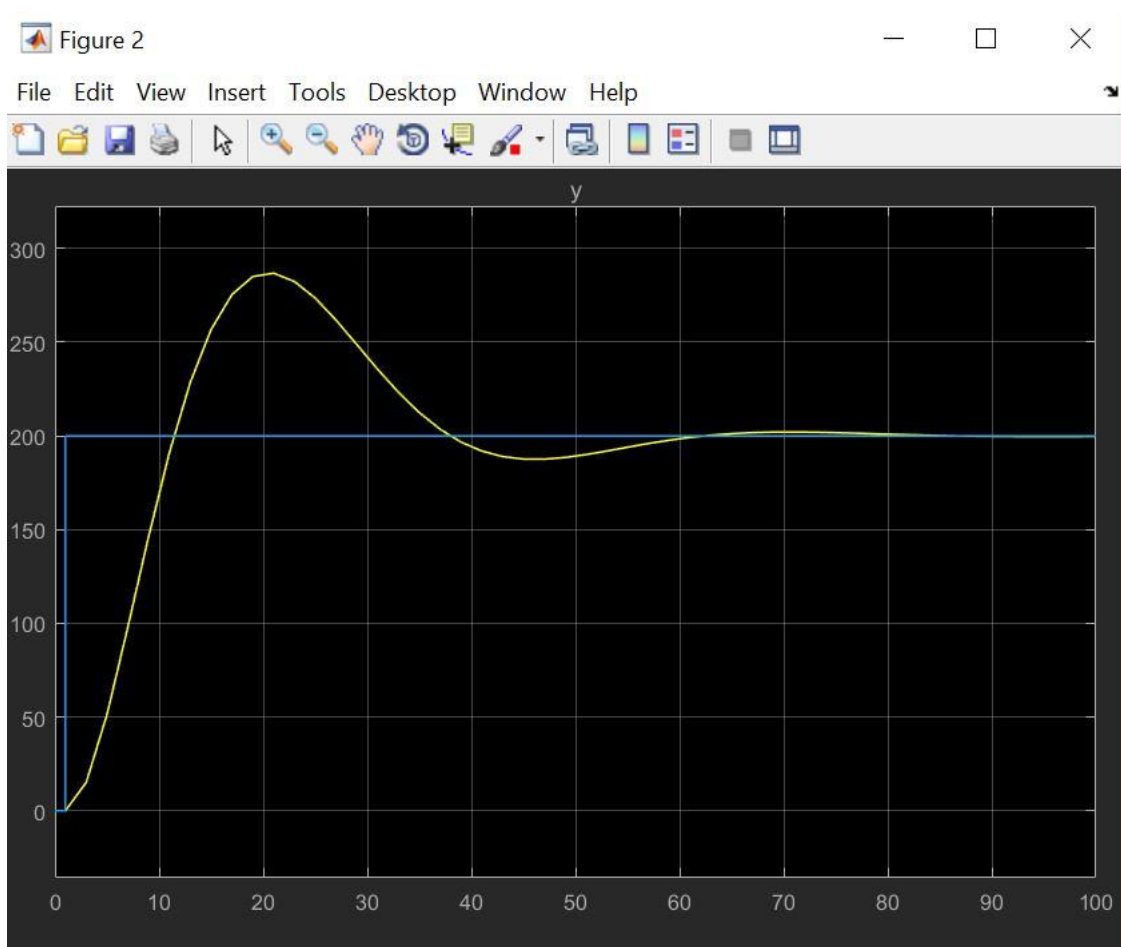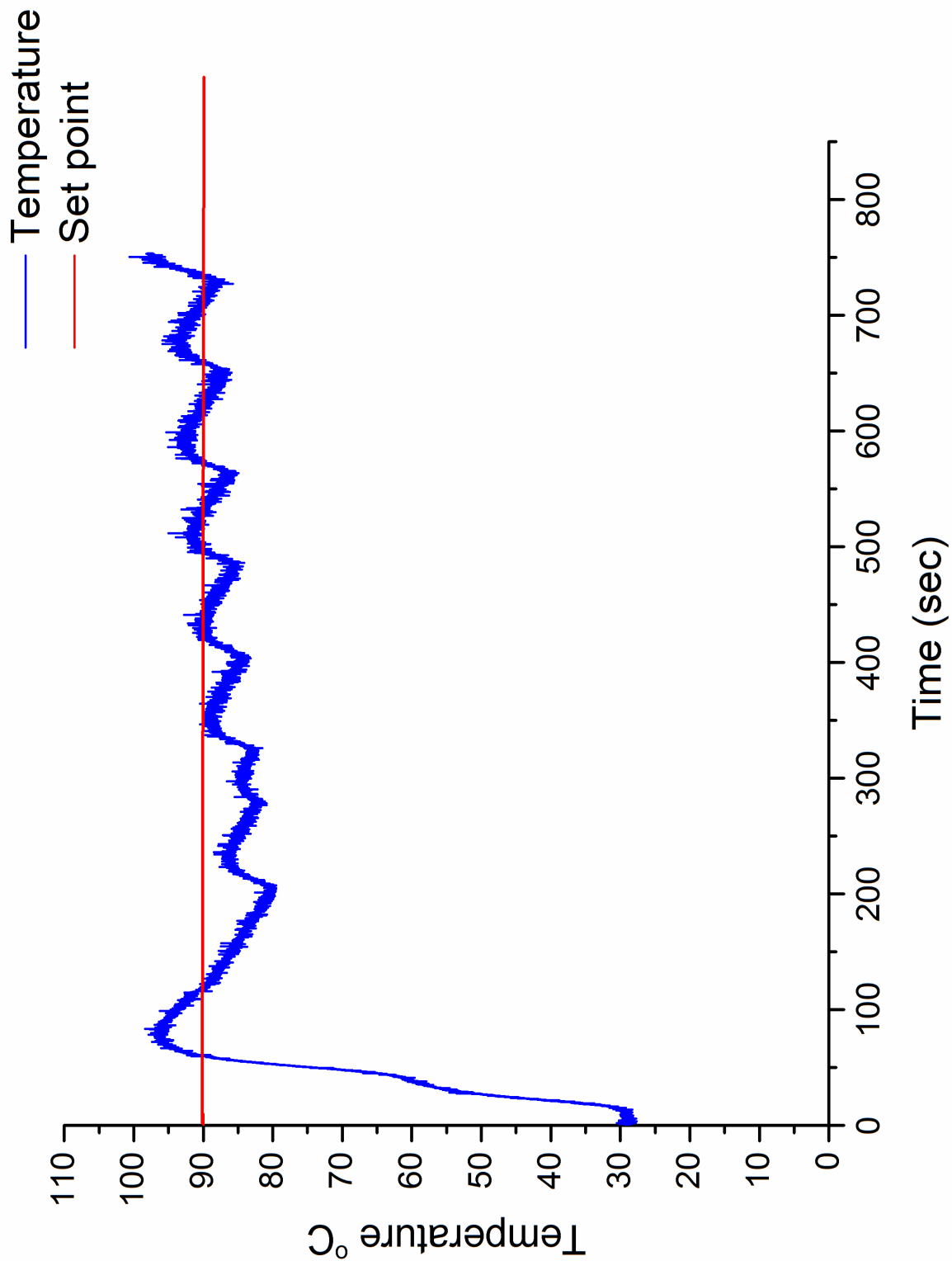$$T_i = 4.T - 0.5T_s \rightarrow 13.366$$

fig: 39 Simulative results from symmetrical optimum method

graph: symmetrical optimum
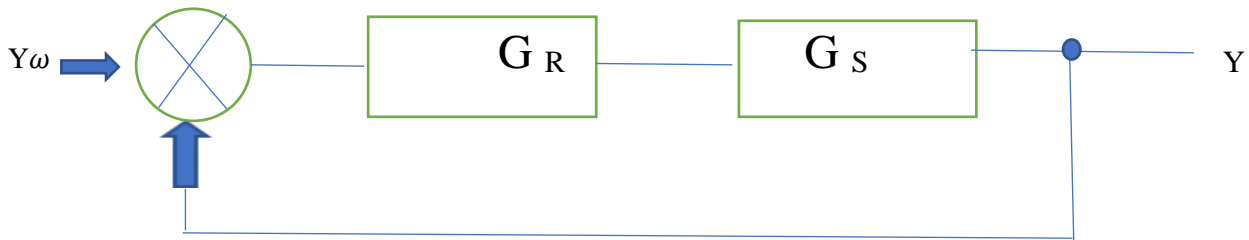
8. 10 Stability of control circuit

fig: 40 Block diagram of dynamic system

G_s = Transfer function of the system.

G_R = Transfer function of the controller.

G_{wy} = transfer function between desired value and output from the control circuit. Output from the control circuit is temperature of the system.

$$G_S = \frac{K}{TS+1} \cdot \frac{1}{S} \qquad\qquad G_R = K_c \left(1 + \frac{1}{T_I} \cdot \frac{1}{S}\right)$$

$$G_{wy}(s) = \frac{G_R(s).G_S(s)}{1 + G_R(s).G_S(s)}$$

$$G_{wy}(s) = \frac{(K_c + \frac{k_c}{T_I S})(\frac{k}{TS^2+S})}{1 + (K_c + \frac{k_c}{T_I S})(\frac{k}{TS^2+S})}$$

$$= \frac{\left(\frac{S k_c T_I + K_c}{T_I S}\right) \cdot \left(\frac{k}{TS^2+S}\right)}{1 + \left(\frac{S k_c T_I + K_c}{T_I S}\right) \cdot \left(\frac{k}{TS^2+S}\right)}$$

$$= \frac{\left(\frac{k.k_c(1+sT_I)}{T_I S(TS^2+S)}\right)}{\left(\frac{T_I S(TS^2+S) + K.K_c(1+ST_I)}{T_I S(TS^2+S)}\right)}$$

$$= \frac{k.k_c(1+ST_I)}{T_I.T\, S^3 + K.K_c T_I S + K.K_c + T_I S^2}$$

8.11 Hurwitz criterion of stability

$$H_W = \begin{bmatrix} T_I & KK_C & 0 \\ T_I & KK_C T_I & 0 \\ 0 & T_I & KK_C \end{bmatrix}$$

Where,
H_w = Hurwitz matrix

Taking determinant of H_W

$$\text{Det } H_W = \text{Det} \begin{bmatrix} T_I & KK_C \\ T_I & KK_CT_L \end{bmatrix}$$

$T_I *(K*K_C*T_{I)} - T_I*T *(K*K_C) =$

$13.366*(0.92547*0.1593*13.66) - (13.666*3.354*0.1593*0.92547) = 20.1716$

$20.1716 > 0$ STABLE SYSTEM
　　　　$= 0$ MARGINALLY STABLE SYSTEM
　　　　< 0 UNSTABLE SYSTEM

8.12 advantages, disadvantages and future development

Advantages:

1. Temperature and Fabric Selection will be Displayed on the LCD Screen. (it is quite simple to program the display for our needs and reprogram the display when the needs change for ex- while measurement the display was programmed to show the PI parameters, the width of pulses, the input to coil weather 1 or 0, the timer values (timing) and output from PI).
2. This Digital Iron Box will maintain temperature automatically to a very high degree of accuracy for selected fabric by which life of fabric will be saved.
3. Maintenance of the iron box is eliminated as there is no moving parts unlike in a traditional iron box.
4. Since the control is completely converted in to digital it is highly reliable, and any possibility of failure is eliminated.
5. Economically friendly, replacing of damaged parts is eliminated better controllability and many other safety features can be implemented very easily like automatic trip off etc.

Applications:

a. It can be used for residential purpose.
b. It can be used for small scale industries.

Future Enhancement

1) We can upgrade this state of iron box from Dry to Steam Digital Iron Box.
2) We can switch OFF Iron Box Power Completely when there is no fabric below its surface by using sensors.
3) Only PI parameters are used for the programming of the iron box. After major design upgrades The filter should be implemented within the iron box and the D parameter should be applied as well. The control will be of highest quality with PID parameters. The D parameters are not applied in this project because derivative parameters will act as an amplifier it amplifies noise along with the input, however the noise can be suppressed to minimum if not completely eliminated with suitable filters.

9 Results and conclusion

The functionality of the iron box is verified the most suitable method is optimum symmetric method it yields the best results the temperature deviation is minimum. The PI parameters set by hand or by experimental method needs very long time for precise temperature control.

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LIST OF ABBREVIATION:

1. CAID - Computer Aided Industrial Design
2. CCD - Charged-Coupled Device
3. CCFL - Cold Cathode Fluorescent Lamp
4. DAC - Digital-to-Analog Converters
5. MCU - Microcontroller Units
6. CTMU - Charge Time Measurement Unit
7. MCCP - Multiple Capture Compare Peripheral
8. SCCP - Single Capture Compare Peripheral
9. POR - Power-on Reset
10. PWRT - Power-up Timer
11. OST - Oscillator Start-up Timer
12. PLL - Phase Locked Loop
13. ICSP - In-Circuit Serial Programming
14. RTCC - Hardware Real-Time Clock and Calendar
15. REFO - Configurable Reference Clock Output
16. CLC - Configurable Logic Cells
17. LCD - Liquid Crystal Display
18. PCB - Printed Circuit Board
19. TRIAC - Triode Alternating Current Switch
20. PSV - Program Space Visibility
21. GCC - GNU Compiler Collection
22. NTC - Negative Temperature Coefficient
23. PTC - Positive Temperature Coefficient
24. LED - Light Emitting Diode
25. ICE - In-Circuit Emulation
26. ADC - Analog to Digital Convertor
27. PWM - pulse width modulation

NOMENCLATURE:

1. V_{DD} -   Positive power rail voltage

2. Op-amp -   Operational Amplifiers

3. V_{ac} -   Supply Voltage

4. V_{cc} -   Positive power rail voltage

APPENDIX