Microcontroller Based Temperature Control System Using PIDControl Theory

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Abstract

PIC controlling system is widely used and very popular in industrial control. The aim of this paper is to design Microcontroller based temperature control system and to construct. PIC model 16F877 and LM 35 DZ temperature sensor is used to perform the temperature control system. Serial communication interface is used for the communication. Sensor is placed in specific place which is Sensing environment. Heater is on at the initial state and when the desired point of temperature is reached, the heater is off automatically. The temperature status is shown by monitor. Proportional Integral Derivative control is used for the temperature control system.

1. Introduction

Microcontrollers are widely used in industrial control and many applications. They also provide the capabilities to easily interfacing and programming for electronic applications, that control the real-word and industry.

Since the microcontroller is like a computer contained in a Single chip, it has built-in memory circuits for the program, an input/output parts to communicate with the outside world. It can be use in applications by providing power supply and clocking .The general purpose of a Microcontroller is to receive it's input, process it in digital form and retrieve its outputs. The ability of a microcontroller is to store and run unique programs which are make the microcontroller as the brain of a limitless variety of different applications.

Microcontrollers are constructed by using CMOS technology, which reduce the chip's size and power requirements. PIC are Reduced Instruction Set Computer (RISC) processor which make them relatively easy to write the software. They can be described as a eight bit RISC processor that has build-in clocking, reset, Memory, timers, interrupts, input/output (I/O) ports, and optimal advanced interfacing capabilities [1].

2. Background Theory

The PID control scheme is named after its three correcting terms, whose constitutes the manipulated variable (MV).

Proportional term

The proportional term makes a chance to the output that is proportional, to the current error value. The proportional response can be adjust by multiplying the error by a constant Kp, called the proportional gain.

Integral term

The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. Summing the instantaneous error overtime (integrating the error) gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain and added to the controller output. The magnitude of the contribution of the integral term to the overall control action is determined by the integral gain, Ki.

Derivative Term

The rate of change of the process error is calculated by determining the slope of the error overtime (i.e its derivative with respect to time) and multiplying this rate of change by the derivative gain Kd. The magnitude of the contribution of the derivative term to the overall control is termed the derivative gain, Kd [2] .

$$MV(t) = P_{out} + I_{out} + D_{out}$$

$$MV\ (t) = K_p(et) + K_i \int_0^t e(t)\, dt + K_d \frac{de}{dt}$$

3. Implementation

3.1 Software Implementation

In this thesis, temperature measurement system is designed for, reads the temperature from the sensor and display the temperature continuously with a sampling time delay which is defined by user between each display output. The temperature scale also defined by user in centigrade, or Fahrenheit. The output of the sensor is analog signal, this signal is converted by the A/D CONVERTER in the Microcontroller to convert it to digital. Then scaled and display the temperature on monitor. LM35DZ analog temperature sensor I.C is used for the system. It is three pins I.C PIN1 connects to supply, PIN 2 connects to Ground, and PIN 3 is the output that provides voltage.

Microcontroller is operated from a 4MHZ external resonator(or) crystal.

The thermometer is connected to COM1 serial port of a computer. A terminal emulation program, such as Hyper terminal is activated on the computer to communicate with the thermometer. During this communication the user is prompted to enter the sampling interval and the mode of output required in degrees (c) or degrees(f)

The set-point is assigned by the program and process variable which is come from LM35DZ temperature sensor is put in to PID algorithm and execute until the obtain the desire result. Result is shown on monitor in sampling interval delay error, the difference between set point and process variable is reduced by PID algorithm with microcontroller's output pin and driver circuit. The output pulse for driver circuit is execute from microcontroller and it is determined by programming. The PID control equation and parameters are write in basic language. The PIC Basic Pro compiler convert the equations into source code. The results from LM 35DZ sensor is feedback to the Microcontroller and calculated. After calculating the PID terms, the manipulated variable (MV) is retrieve as the system output.

The control program is write in Microcode studio IDE software. PIC Basic Pro compiler and assembler is used for program and program is burned into the Microcontroller by EPIC WIN software.

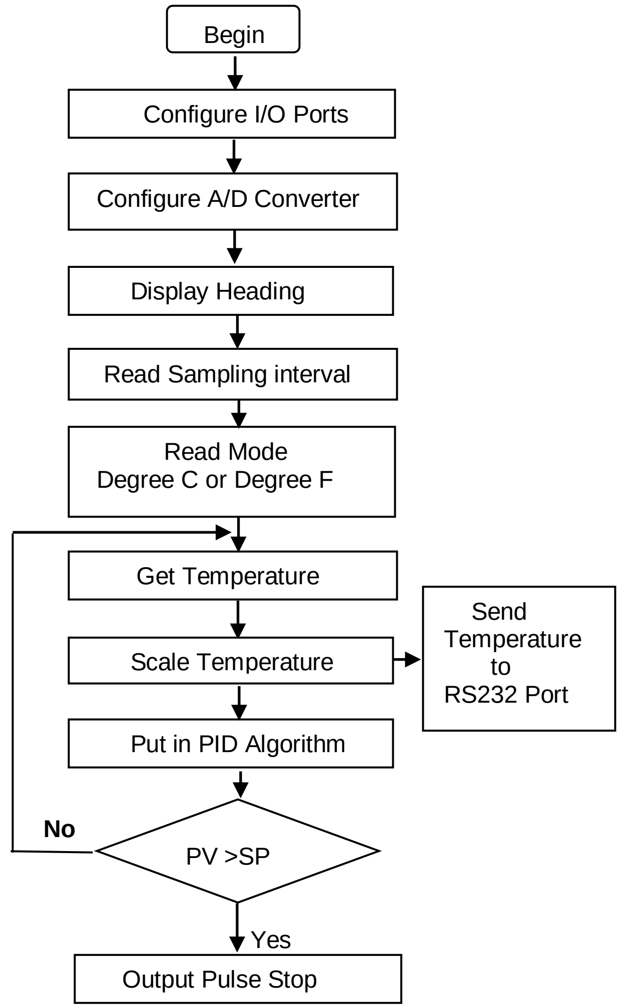

Figure 1. Flowchart of the System

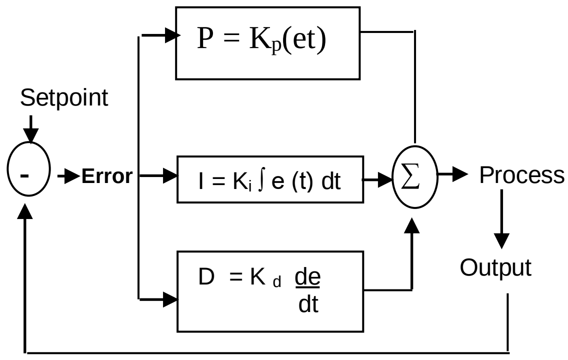

Figure 2. Block Diagram of the System

3.2 Hardware Implementation

The circuit design can be construct with any microcontroller, which has built in ADC (analog to digital converter). PIC 16f877 is the 40 pin microcontroller and has a 10 bit resolution of 8 channels analog to digital converter.

The temperature sensor LM35DZ is connected to the PORT A, bit 0(AN0) of microcontroller. PORTB 0 and PORT B 1 (RB 0and RB1)is assigned as the TX (TRANSMIT) and RX (RECEIVED) of the serial interface.

In usual , RS 232 voltage level is +12v is logic 1 also called the Mark and -12v is logic 0 and also called the space. MAX202 chip convert 0 to +5v level from microcontroller to +12v of RS232 level. Similarly +12v or -12v of RS 232 level from 0 to +5v level of CMOS.

3.2.1 ADC Resolution calculation of PIC 16F877

The built in analog to digital converter with 10 bit resolution of PIC 16f877 is needed to calculate ADC Conversion for operation.

ADC(resolution)=Vref/2power N
VREF = 5V,N=10(resolution)
ADC (resolution) = 4.8828 mv /bit

3.2.2 Design Calculation For Instruction Cycles In PIC 16F877

PIC 16F877 DC 20MHz clocks and DC 200ms instruction cycles. It can be used between 4MHz and 20MHz for operating speed. Frequency 4MHz (CRYSTAL) is chosen for the operation.

Frequency (F) = 4MHz
Period (one clock cycle) T=1/F
T=0.25 microsecond
Instruction cycle = 4 clock cycle
one instruction = 0.25*4 = 1micro second

3.2.3 Microcontroller Based Temperature Control System Circuit Diagram

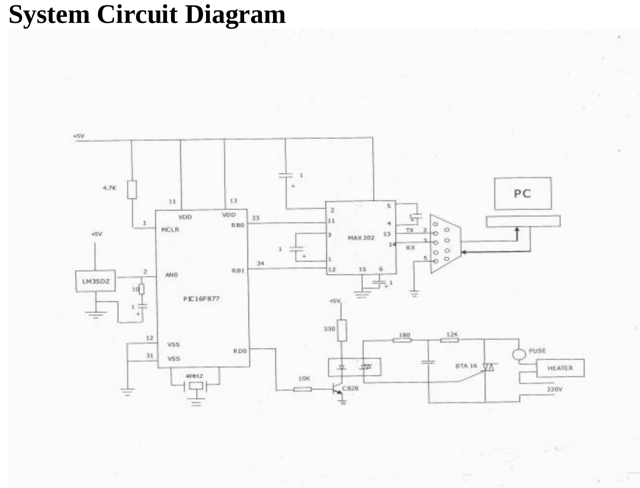

Figure 3 . Over All Circuit Diagram

In general RS 232 communication, use of the frame for transmitting or receiving data. Each frame contains

1. 1 start bit
2. 8data bits
3. NO parity bit
4. 1 stop bit

Normally, data line is the logic 1 (Mark) and it is also at the idle state. Communication begin when the logic 0 State of start bit is sending for bit time. Then each 8 data bits are sending at bit time interval, when the stop bit Is send the communication completed. Bit time is depend on the Baud rate (ie number of bit per second). The general Baud rates are 2400,4800,9600,19200,38400 etc. For example, we used the Baud rate of 9600, this means 9600 bits of information are send in one second.

4.Experimental Result

Experimental result of the manual tuning and effects of increasing parameters are on the table 1.1.

The effects of increasing the parameters of PID constants (gains) are, if the proportional constant (Kp) is increase, the system's output can be greater than set-point (user define) easily and the time to get the system's output (PID output) is greater than set-point also called the system overshot and system's stable output is retrieve in short time. If the derivative constant (Kd) is increase, the system's output is decrease and the time to retrieve the output is indefinite.

Table 1.1 Gain Effects on System

Effect of increasing parameter		
Parameter	Risetime	overshoot
Kp	Decrease	increase
Ki	Decrease	increase
Kd	Indefinite	decrease

Table 1.2 Calibration of LM 35 DZ

Situation	Temperature	Corresponding Output
Ice point	4°C	40 mv
Room temperature	25°C	250 mv
Boiling point	98°C	980 mv

The temperature sensor LM35DZ has the reference voltage of 10mv per degree centigrade. The sensor sense the temperature and retrieve the voltage (milli volts) as the results. The range of output voltage is 10 milli volts per 1 degree centigrade.

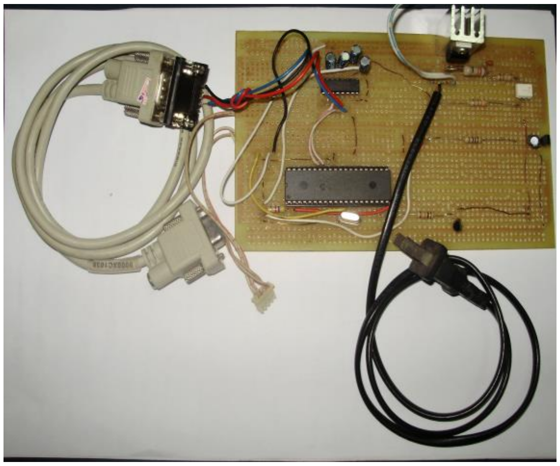

Figure 4. Temperature Control Circuit

5. Conclusion

In this system, the temperature range of the controller is between 25ºC and 60ºC. The range of the controller is very on the type of the sensor. For other higher temperature range, LM 35DZ sensor can be replaced by thermocouple which can sense the above 1000ºC range.

Desired temperature range (set-point) is determine by the PID control program. Program is written with PIC Basic Pro and burned into microcontroller by using EPIC WIN software. The only one set-point is less reliable than multiple set-point. To get the more reliable controller, key board can be used to enter multiple set-points.

Proportional, Integral, Derivative control theory is used for this thesis. PID Tuning technique and equations can be used as further extension to achieve the good performance PID controller.

6. References

[1] D.oh, 2005, "Tutorial; Microchip PIC 16F877 Microcontroller"

[2] "Introduction to closed-loop control, proportional integral Derivative, PID" http://www.omega.com

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[4] "Temperature sensor ICLM 35DZ and datasheets" http://www.microchip.com

[5] "Temperature controller guide" http://www.waltlow.com