PIC-circuit Implementation of Room Temperature Controller By using PIC16F873

Nan Myint Myint Htwe, Thu Zar Aung, Su Su Win
Computer University (Myeik)
htwelayo8@gmail.com, thuzaraung@gmail.com, susuwin.most@gmail.com

Abstract

This paper deals with the PIC-circuit implementation of room temperature controller by using PIC16f873. Temperature controller-designed and constructed is PIC–based temperature controller (PIC16F873). In this control system, PIC16F873 is used as the heart of the temperature controller. Semiconductor temperature sensor, LM35DZ is used for data acquisition. LM35DZ temperature sensor, it senses the temperature and after amplification is then fed to the microcontroller. The microcontroller (PIC16F873) is the equipment which adjusts the temperature of the room automatically. On/Off operation is made by the set point using relay switch. Control mode (works over preset or below preset) is changed with a switch, two temperature sensors are used. This microcontroller can program with assembly language using microchip MPLAB IDE software development tools. Finally the output will show display control of six 7 segments LEDs, readings of the three BCD switch and reading up/down switch are performed. The developed software is highly accurate and works at a very high speed.

1. Introduction

Control systems are everywhere around us and with us. A control system is a group of components that maintains a desired result by manipulating the value of another variable in the system. The basic for analysis of a system is the foundation provided by linear system theory, which assumes a cause- effect relationship for the process, which in turn represents a processing of the input signal to provide an output signal variable, often with power amplification. Control systems are classified in a number of different ways. They are basically classified as closed loop or opened loop, depending on whether or not feedback is used.

Open loop control has opened loop operation. An opened loop control system utilizes an actuating device to control the process directly without using feedback. The effects of known disturbances alone can be countered. Other disturbances use cannot be taken into account. In opened loop control the controller is blind to what actually take places at the output end and goes on driving the plant in fixed and predetermined manner.

In contrast to an opened loop control system, a closed loop control system utilizes and additional measure of the actual output to compare the actual output with the desired output response. The measure of the output is called the feedback signal.

A closed loop control system is a control system that tends to maintain a prescribed relationship of one system variables to another by comparing functions of these variables and using the difference as a means of control. A closed loop control system of the uses a function of prescribed relationship between the output and reference input to control the process. Often the difference between the output of the process under control and the reference input is amplified and used to control the process so that the difference is continually reduced. The feedback concept has been the foundation for control system analysis and design.

Closed loop control has closed loop operation using negative feedback. The effects of disturbances are countered by virtue of negative feedback. Closed loop operation can be unstable even if the plant is stable. In closed loop or feedback control the controller notices what actually takes place at the output end and drives the plant in such a way as to obtain the desired output. There can be two different cases of feedback control. One is to reduce the effect of disturbances. Certain variables of a process such as controlled variable should be maintained at given fixed values despite disturbances. Such a control is called set point control, or regulation, or control for disturbances rejection.

A closed loop control system use a measurement of the output and feedback of this signal to compare it with the desired output (reference or command). Temperature control is a variation of the feedback control. The principle of temperature control is explained in the example of room temperature control. [1,3]

2. Description about the Microcontroller

This section gives a brief idea about the Peripheral Interface Controller (PIC) microcontroller, its advantages over microprocessors, its core features, block diagram, pin diagram and its description.

2.1. Microcontroller

Circumstances that we find ourselves today in the field of microcontrollers had their beginnings in the development of technology of integrated circuits. This development had made it possible to store hundreds of thousands of transistors into one chip. That was a prerequisite for production of microcontrollers, and adding external peripherals such as memory, input-output lines, timers and other made the first computers. Further increasing of the volume of the package resulted in creation of integrated circuits. These integrated circuits contained both processor and peripherals. That is how the first chip containing a microcomputer, or what would later be known as a microcontroller came out.

2.2 Microcontroller versus Microprocessors

Microcontroller differs from a microprocessor in many ways. First and the most important is its functionality. In order for a microprocessor to be used, other components such as memory, or components for receiving and sending data must be added to it. In sort, it means that microprocessor is the very heart of the computer. On the other hand, microcontroller is designed to be all of that in one. No other external components are needed for its application because all necessary peripherals are already built in to it. Thus, we save the time and space needed to construct devices. [5]

2.3 PIC16F873

It belongs to a class of eight bit microcontrollers of RISC architecture.

2.3.1 Program Memory (FLASH)

This concept is used for storing a written program. Since memory is made use of in FLASH technology, it can be programmed and cleared more than once, it makes this microcontroller suitable for device development.

2.3.2 EEPROM

It is a device wherein the data memory needs to be saved when there is no supply. It is usually used for storing important data that must not be lost if supply suddenly stops. For instance, one such data is an assigned temperature in temperature regulators. If this data is lost during a loss of supply, we would have to make the adjustment once again upon return of supply. Thus our device looses on self reliance.

2.3.3 RAM

Data memory is used by a program during its execution. All inter-results on temporary data stored in RAM and they are not crucial to running a device during a loss of supply.

2.3.4 PORTA, PORTB and PORTC

These are physical connections between the microcontroller and the outside world. PORTA has five pins, PORTB and PORTC has eight pins.

2.3.5 Free Timer

It is an eight-bit register inside a microcontroller that works independently of the program. On every fourth clock of the oscillator, it increments its value until it reaches the maximum, and then its starts counting over again from zero. As we know the exact timing between each two increments of the timer contents, timer can be used for measuring the time, which is very useful with some devices.

2.3.6 Central Processing Unit

It has a role of connective elements between other blocks in the microcontroller. It coordinates that work of other blocks and executes the user program.

2.4 CISC and RISC

It has already been said that PIC16F873 has RISC architecture. This term is often found in computer literature. Harvard architecture is a newer concept than von-Neumann's. It rose out of the need to speed up the work of a microcontroller. In Harvard architecture, data bus and address bus are separate. Thus, a greater flow of data is possible through the central processing unit, and of course, a greater speed of work. Microcontrollers with Harvard architecture are also called "RISC microcontrollers." RISC stands for reduced instruction set computer. Microcontrollers with von-Neumann's architecture are called as the "CISC microcontrollers". The title CISC stands for 'complex instruction set computer'. Since PIC16F873 is a RISC microcontroller which means that it has a reduced set of instructions, more precisely 35 instructions.

2.5 Pin Diagram

The pin diagram of PIC16F873 is as shown in the Figure 1.

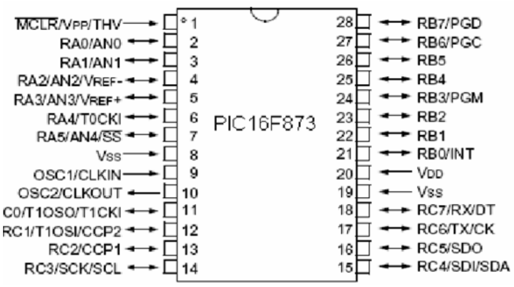

Figure 1 Pin details of PIC microcontroller

2.6 Device Overview

PIC16F873 device comes in 28-pin package. This does not have a parallel slave port implemented.

2.7 PIC16F873 Block Diagram

The block diagram of the PIC16F873 is shown in Figure 2. [2]

Device	Program FLASH	Data memory	Data EEPROM
PIC16F873	4K	192 Bytes	128 Bytes

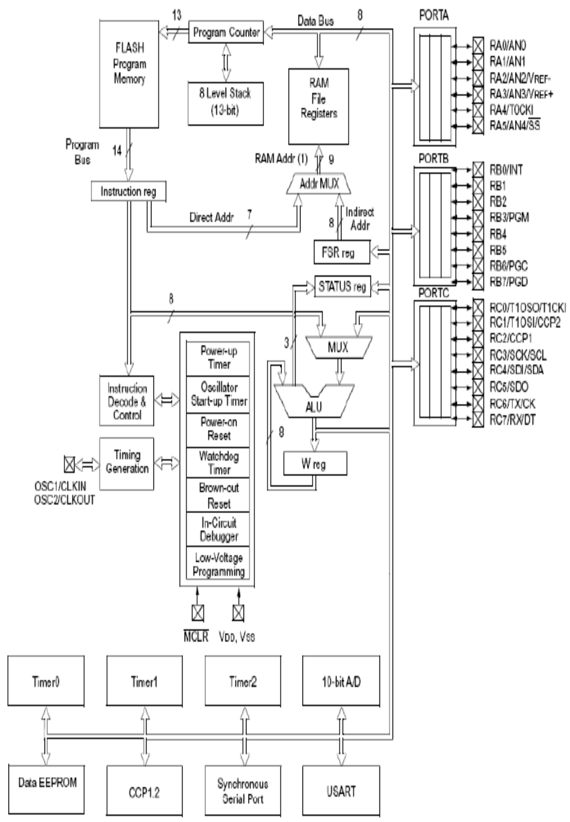

Figure 2 Block Diagram of the PIC16F873 Microcontroller

2.9 STATUS Register

The STATUS register contains the arithmetic status of the ALU, the RESET status and the bank select bits for data memory. The STATUS register can be the destination for any instructions, as with any other register. If the STATUS register is the destination for any instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. These bits are set or cleared according to the device logic. Furthermore, the TO and PD bits are not writable, therefore, the result of an instruction with the STATUS register as destination may be different intended. For example, CLRF STATUS will clear upper three bits and set the Z bit. This leaves the STATUS register as 000u u1uu (where *u* = uncharged). It is recommended, therefore, that only BCF, BSF, SWAPF and MOVWF instructions are used to after the STATUS register, because these instructions do not affect the Z, C or DC bits from the STATUS register. For other "instructions set summary."

2.10 OPTION_REG Register

The OPTION_REG register is a readable and writable register, which contains various control bits to configure the TMRO pre-scaler / WDT post-scaler (single, assignable register known also as pre-scaler), the external INT interrupt TMRO and the week pull-ups on PORTB. The detailed description about each bit of status register and option register is also studied prior to the design.

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2.11 Memory Organization

There are three memory blocks in PIC16F873. The program memory and data memory has separate buses so that concurrent access can occur and is detailed in this section.

2.12 Program Memory Organization

PIC16F873 have program counter capable of addressing an 8K × 14 program memory space. The reset vector is at 0000h and the interrupt vector is at 0004h.

2.13 Data Memory Organization

The Data Memory is partitioned in to multiple banks, which contain the general- purpose register and special function register bits RP1 (STATUS <6>) and RP0 (STATUS <5>) are the bank select bits as shown in the table 1.

TABLE 1 Register Banks

RP1 : RP0	Bank
00	0
01	1
10	2
11	3

2.14 Program Memory Map and Stack

The program memory map and stack organization with its addresses was also studied in brief prior to the design of the temperature sensor. It consisted of 8 stack levels. The on chip program memory was divided into pages. The program memory address ranges from 0000h to 1FFFh. When a call instruction is executed, the address of the next instruction will be stored into the stack memory. The stack works in first out manner. After the return instruction is executed, the address stored in the stack is retrieved and loaded back into the program memory.

2.15 Analog to Digital Converter Module

The analog to digital converter module has five inputs for the 28-pin devices. The analog input charges a sample and hold capacitor. The output of the sample and hold is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. The analog to digital conversion of the analog input signal results in a corresponding 10-bit digital number. The analog to digital converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in SLEEP mode, the analog to digital clock must be derived from the analog to digital internal RC oscillator. The A/D module has four registers. These registers are:

1. A/D result high register (ADRESH)
2. A/D result low register (ADRESL)
3. A/D control register 0 (ADCON0)
4. A/D control register 1 (ADCON1)

2.16 ADCON0 Register (Address: 1Fh)

ADCON0 register controls the operation of the A/D module. The ADCON1 register, configures the functions of the port pins. The port pins can be configured as analog inputs are as digital input or output.

2.17 ADCON1 Register (Address 9Fh)

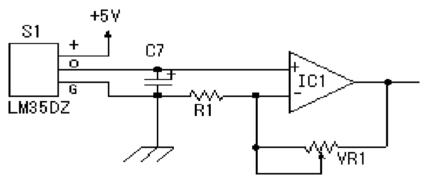
The ADRESH and ADRESL registers contain the 10-bit result of the A/D conversion. When the A/D conversion is complete, the result is loaded in to this A/D result register pair, the GO/DONE bit (ADCON0 (second bit)) is cleared and the A/D interrupt flag bit ADIF is set. After the A/D module has been configured as desired the selected channel must be acquired before the conversion is started. The analog input channels must have there corresponding TRIS bits selected as an input.

3. Design and Hardware Implementation of Temperature Controller

This section gives a brief description about the design and hardware implementation of temperature controller that used for the design and fabrication of temperature sensor circuit external equipment drive circuit, power supply, amplifier and LED display and SW reading circuit.

3.1 Temperature Sensor Circuit

A temperature sensor (LM35DZ) can measure from 0°C to 100°C. However, the output is 0V at 2°C. Therefore, the voltage of minus is required in order to measure 0°C. Since the minus power supply is not used with this equipment, the measurable temperature is above 2°C. The output voltage in 32°C is 300mV.



igure 3 Temperature Sensors LM35DZ

The output voltage of a sensor is amplified by an operational amplifier, and is inputted into the A/D converter of PIC. Proofreading of a temperature display is performed by adjusting the gain of an operational amplifier by VR. This circuit shown in figure 3, in order to simplify a circuit, the operational amplifier which operates with a plus single power supply is used.

3.3.1 Non-Inverting Amplifier

An op-amp connected in a closed loop configuration as a non-inverting amplifier to control the amount of voltage gain. The input signal is applied to the non-inverting input. The output is applied back to the inverting input through the feedback circuit formed by Ri and Rf.

An operational amplifier can adjust the gain (the degree of amplification) of amplifier by changing the resistance of feedback. There are two kinds of amplification circuits. They are Inverting Amplifier and Noninverting Amplifier. In case of Inverting Amplifier, the gain is decided by the ratio of Ri and Rf, but the phase of input and output is reversed. In case of Noninverting Amplifier, the gain

is the value which added 1 to the ratio of Ri and Rf, and the phase of input and output is same.
An exact gain value is unnecessary in this circuit.
LM358 which operates only with a plus power supply is used for the simplification of a power supply circuit.

The output of a temperature sensor changes at a 10mV/°C rate on the basis of 2°C. Therefore, the output voltage of 30°C is 280mV. Since this voltage is low, accuracy sufficient by the A/D converter of PIC is not acquired. Therefore, it is amplifying by the operational amplifier.

3.2 External Equipment Drive Circuit

This is the circuit which controls external equipment shown in figure 4. Although based on the drive current of the relay to be used, in this case, the drive circuit which uses a transistor is adopted.

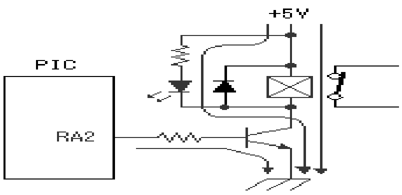


Figure 4 Drive Circuit

3.3 Power Supply Circuit

This is the circuit which makes the power supply of +5V. It is a general circuit. Although the output of a transformer was 12V AC, the output of the rectifier by a diode when 150mA flows was the voltage of about 11V DC. This is dropped on a regulator 5V as shown in figure 5.The temperature of a regulator goes up by this power consumption. Therefore, a heat sink is attached to the regulator.

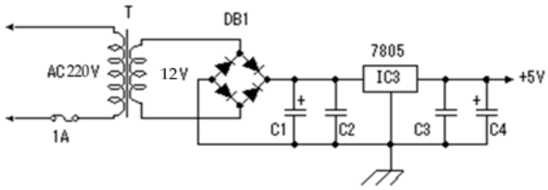


Figure 5 Power Supply Circuit

3.4 LED Display and SW Reading Circuit

7 bits of low ranks of PORTB are used for lighting of 7 segments LED, and reading of BCD switch in common. PORTC and the 8th bit of PORTB are used for designation of a device as in shown figure 6. The mode change of PORTB is required of LED control and BCD-SW control. This change is performed by software.

The diode connected to the BCD switch is for prevention of illegal current. With a BCD switch, a common terminal and each terminal corresponding to a bit short-circuit by setup. If there is no diode, the setting state of a switch will influence operation of other devices. In the case of a silicone diode, VF is about 0.6V. When L level detection of the PIC cannot be normally carried out with this voltage, it is better to change a diode into other kinds. (Germanium, etc). In the case of the left example, even if SW2 is set as 6, if SW1 is set as 5, the terminal 1 of SW1 is set to 0V through the terminal 4 of SW1, so a normal preset value cannot be read.

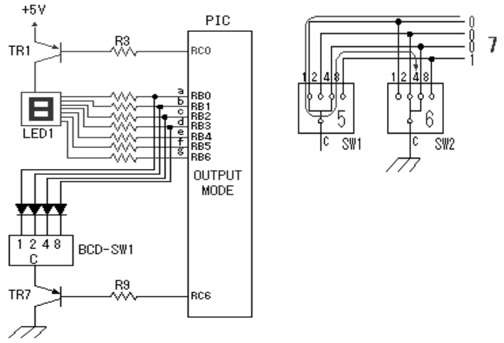


Figure 6 LED Display and SW Circuit

4. Overview of the Temperature Control System

The block diagram is a room temperature controller with PIC as shown in figure 7. This equipment uses two temperature sensors, drives external equipment, and keeps the temperature of the room at preset temperature. The purpose of this equipment is for preventing room temperature going up with the heat of the computers. Electric cost become high if an air-conditioner is always operated.

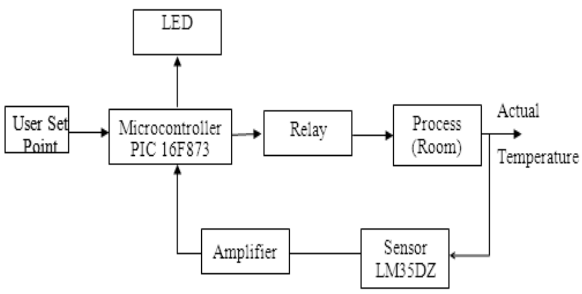


Figure 7 The System Block Diagram

Then, the equipment which adjusts the temperature of the room automatically using some ventilation fans is made. The function below preset temperature is a function attached moreover. It is used for temperature control, such as a greenhouse. Control mode (works over preset or below preset) is changed with a switch and two temperature sensors are used.

One is indoor temperature detection and another is air-conditioner temperature detection. The ventilation fan is the type which performs inhalation of air and an exhaust gas simultaneously used in a bathroom etc. An open air temperature sensor is for stopping a ventilation fan, when the temperature of the open air is higher than an indoor temperature. Open air temperature detection is used only when using a ventilation fan in summer. Since a winter season does not need to take the open air into the room, control by open air temperature is not carried out. Figure 8 shows the flow chart of the system. The photo of the PIC- based temperature controller complete circuit diagram for PIC16F873 controller is shown in figure 9.

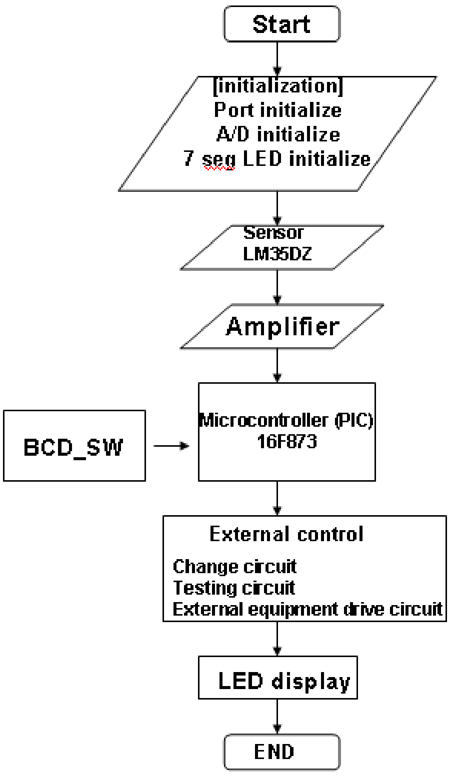


Figure 8 Flow Chart of the Whole System

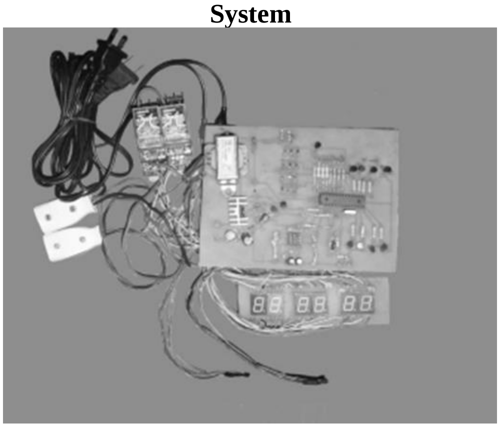


Figure 9 Photo of the Complete Circuit Diagram for PIC16F873 Controller

5. Conclusion

Our country is a developed country and moving toward an automated area of engineering. Temperature control is a part of automatic control engineering and performing of our country. It is expected to be a tremendous beneficial to many areas such as temperature control in plastic works, temperature control in oven, temperature control system used in industries, etc. This paper is mainly focused on PIC based temperature control with On/Off. The temperature controller with LED seven segment provided favorable results using LM35DZ temperature sensor and PIC16F873.PIC based control is constructed for simplicity and reduced hardware and low cost. The software program was used to test the system and compensation methods were found to be necessary. In this control system, we have used a relay like a solid state to switch ON and OFF. So ON/OFF action of this system is more convenient than EMR. In the experiment, 18^0C set point is used. According to the set point, if the function has below the set point, it will cause the relay "Off" and if the function has over the set point, it will cause the relay "On".

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