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Microcontroller Based Automatic Temperature Control System

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ABSTRACT

The microcontroller based temperature control system controls the temperature of any device according to its requirement for any industrial application. At the heart of the circuit is the PIC 16F887A microcontroller which controls all its functions. A temperature sensor thermocouple is used for sensing the temperature of environment and the system displays the temperature on a seven-segment display in the range of 0˚C to 750˚C. This temperature is compared with the value stored by the user and if the temperature goes beyond the preset temperature then heater will switch off and if temperature goes below to preset value then heater will switch on. AC bulb is interfaced with the microcontroller which is done with the help of a relay and on npn transistor.

1. INTRODUCTION

Temperature is one of the main parameter to control in most of the manufacturing industries like chemical, food processing, pharmaceutical etc. In these kinds of industries, some product need the required temperature to be maintained at highest priority the product will fail. So the temperature controller is most widely used in almost all the industries. The goal of this project is to design an ambient temperature measurement and control circuit. The motivation for the project is the fact that temperature measurement has become an integral part of any control system operating in a temperature sensitive environment and the various learning outcomes associated during the implementation of the project.

It is basically a close loop control system. There are two types: ON-OFF type or continuous type system. ON-OFF type – Temperature is sensed, displayed and it is compared with set value. If it is greater, then it switches off the heating element and if it is less, then switches on the heating element. Continuous type, Temperature is sensed, displayed and it is compared with set value. If it is greater/less, then control the heat produced by heating element by changing its supply current.

In this project ON-OFF type controller has been implemented. Here the set value for temperature can be externally set by user. The actual temperature is sensed by the thermocouple temperature sensor. It is displayed on common cathode seven-segment LEDs with the set value. If it exceeds the set value the heater is turned off. After then when temperature falls below the specified limit again heater is turned on.

2. METHODOLOGY

The circuit presents the design, construction, development and control of automatic switching electric heater. The idea is based on the problem occurs in human's life nowadays by improving the existing technology. The Peripheral Interface Controller (PIC) based automatic temperature control system is applied to upgrade the functionality to embed automation feature. The electric heater will automatically switch on according to the temperature falls below the specified limit. The system monitors the temperature from the thermocouple temperature sensor, where it will control the electric heater according to the setting values in the programming. The system indicates the temperature from the PIC 16F887A, and it will display it on the common cathode seven-segment LED display.

If the electric heater temperature goes beyond the preset temperature, then the electric heater will switch off and if temperature goes below to preset value then electric heater will switch on. In this way, the electric heater's temperature can be maintained preset temperature value. It also provides a security characteristic, where it detects on extremely high temperature.

3. Pre – Project Concepts

PIC 16F887A is the Microchip's PIC microcontroller and it is 40 pins enhanced flash/ EEPROM microcontroller. At first a frequency should be set and here it is set to 8 MHz which gives a better performance.

3.1 Instruction Cycle / Machine Cycle

The time required to execute 1 instruction is called instruction cycle or machine cycle. The value can be calculated as 1 machine cycle is equal to eight time period of simply 8T. Therefore,

Frequency, $f = 8\ \text{MHz}$

$$T = \frac{1}{f} = \frac{1}{8} = 0.125\ \mu s$$

So, 1 machine cycle = 8T = (8 * 0.125) µs = 1 µs.

This is the time required to execute one instruction for this microcontroller. So it can be assumed that it is really very fast.

3.2 Pin Configuration

As we have discussed it before that, this microcontroller has 40 pins. Each and every pin has it owns functions. Some are input pins and some are output pins. There are also some pins for the voltage supply and some pins are for ground. There are some ports like PORT-A, PORT-B, PORT-C, PORT-D and PORT-E. PORT-E has 4 pins and all the other ports have 8 pins for their purposes. The pins connection diagram of a PIC 16F887A is shown in Figure 1. Thermocouple temperature sensor is connected to pin 8 (RE_0 /AN5) input of this microcontroller IC. According to that reading, we will see the output in the display unit. It is the output part of the microcontroller. At inside there are lots of general purpose register and special function registers.

General-purpose registers are used for storing temporary data and results created during operation. Some special function registers are: STATUS register, OPTION-REG register, INTCON register, TMR0 register, ADCON0 register, ADCON1 register, ADRESH and ADRESL register etc. Special-function registers are also RAM memory locations, but unlike general purpose registers, their purpose is predetermined during manufacturing process and cannot be change.

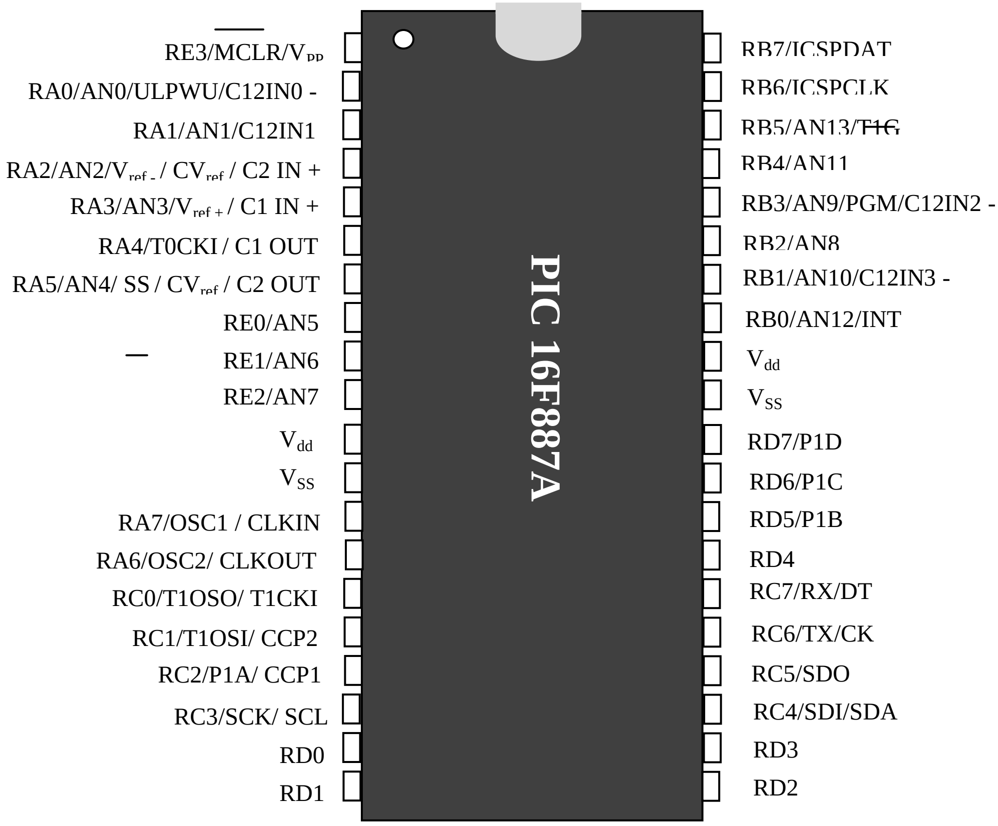


Figure 1. Pin connection diagram of a PIC 16F887 microcontroller IC

3.3 Analog Modules

An analog-to digital converter is an electronic circuit which converts continuous signals to discrete digital numbers. This module is used for input pin voltage measurement (analog value). The result of measurement is a number (digital value) used and processed later in the program. The PIC 16F887 contains 14 analog inputs. They enable the microcontroller to recognized, not only whether a pin is driven to logic zero or one (0 or +5V), but to precisely measure its voltage and convert it into a numerical value, i.e. digital format.

The module is under the control of the bits of four register:

- ADRESH - Contains high byte of conversion result;
- ADRESL - Contains low byte of conversion result;
- ADCON0 - Control register 0; and
- ADCON1 - Control register1.

The ANSEL and ANSELH registers are used to configure the input mode of an I/O pin to analog or digital. To configure a pin as analog input, the appropriate bit of the ANSEL or ANSELH registers must be set (1). To configure pin as digital input/output, the appropriate bit must be cleared (0). ADCON0 register controls the operation of the A/D module. The first bit of ADCON0 register is set to 1, and then the conversion starts. The converter generates a 10-bit binary result using the method of successive approximation and stores the conversion results into the ADC register (ADRESL and ADRESH). By selecting voltage reference $V_{ref\,-}$ and $V_{ref\,+}$, the minimal resolution or quality of conversion may be adjusted to various needs.

3.4 EEPROM

The PIC 16F887 microcontroller has 256 locations of data EEPROM controlled by the bits of the following register:

- EECON1 (Control register)
- EECON2 (Control register)
- EEDAT (Saves data ready for write and read)
- EEADR (Saves address of EEPROM location to be accessed)

3.4.1 *Write to Data EEPROM Memory*

In order to write data to EEPROM memory, first it is necessary to write to the EEADR register first and data to the EEDAT register afterward. Then you have to follow a special sequence to initiate write for each byte. Interrupts must be disabled during this procedure.

3.4.2 Read from EEPROM Memory

In order to read data EEPROM memory, follow the procedure below:

(a) Write an address (00h – FFh) to the EEADR register.

(b) Select EEPROM memory block by clearing the EEPGD bit of the EECON1 register.

(c) To read location, set the RD bit of the same register.

(d) Data is stored in the EEDAT register and ready to use.

4. Design and Construction of the system

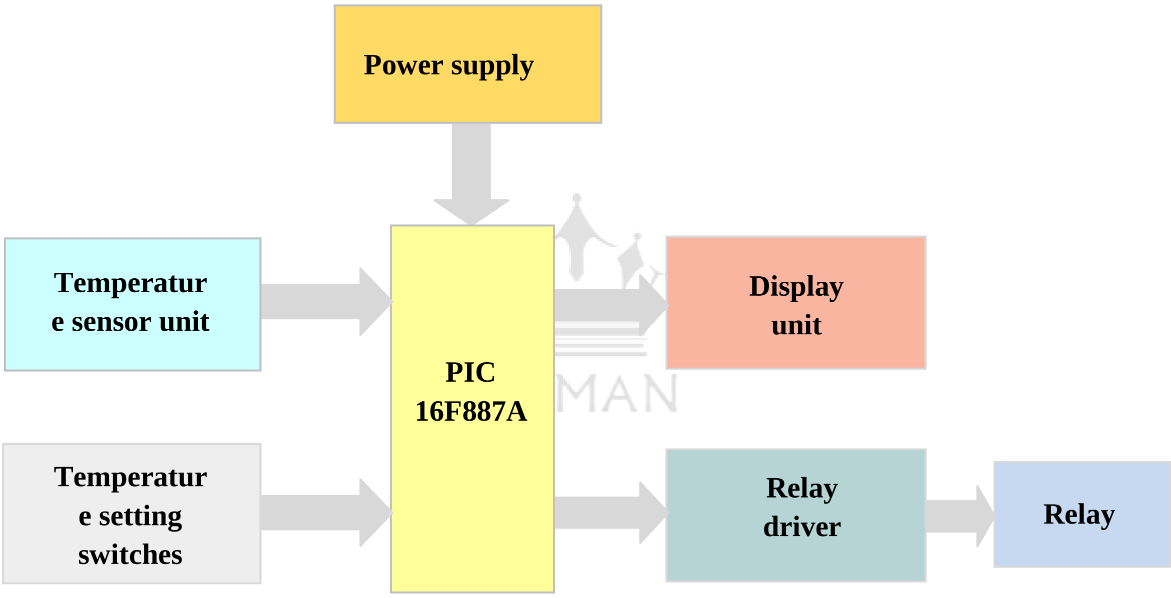


Figure2. General block diagram of proposed automatic temperature control system

General block diagram of the proposed microcontroller based automatic temperature control system has been Figure 2. The system comprises MCU (microcontroller unit), temperature indicator unit, a temperature sensor unit, one relay and some passive component. Two three digit seven-segment LEDs are assembling as temperature indicator unit. One three digit seven-segment LED display is used to display the current temperature and the other is setting temperature.

Thermocouple temperature sensor is used to sense the temperature of electric heater. The output of the thermocouple temperature sensor is connected to bit 0 of PORT E (RE_0) of the

PIC microcontroller via 100 kΩ variable resistor. Require temperature can be preset by four push button switches. These switches are connected to PORT A input (RA_1 – RA_4) of the PIC 16F887A microcontroller IC. Complete schematic diagram for this construction is shown in Figure 3.

The only IC, PIC 16F887A is used with internal clock cycle. The internal oscillator is used to execute the program.PIC 16F887A is controls the two three digit seven-segment LEDs module via PORT B (sRB_0 - RB_7), using PORT D output (RD_0 – RD_5) for the digit select enable signal.

4.1 Hardware Design

The implementation of practical circuit has been designated using Proteus software. Moreover, the circuit is also simulated using this software before practical implementation. The simulation window of Proteus for the microcontroller based temperature control system is shown in Figure 4.The result of simulation ensures that the circuit works at proper way. The practical implementation of simulated circuit has been presented in Figure 3.

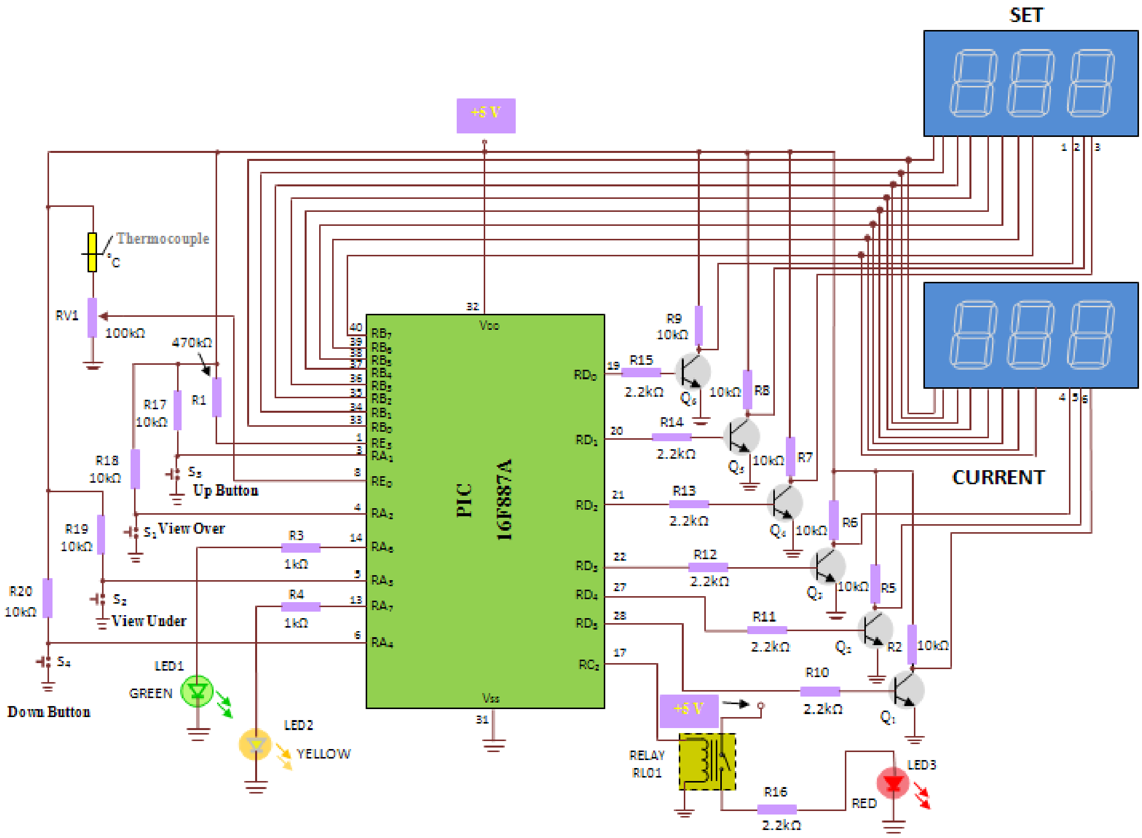
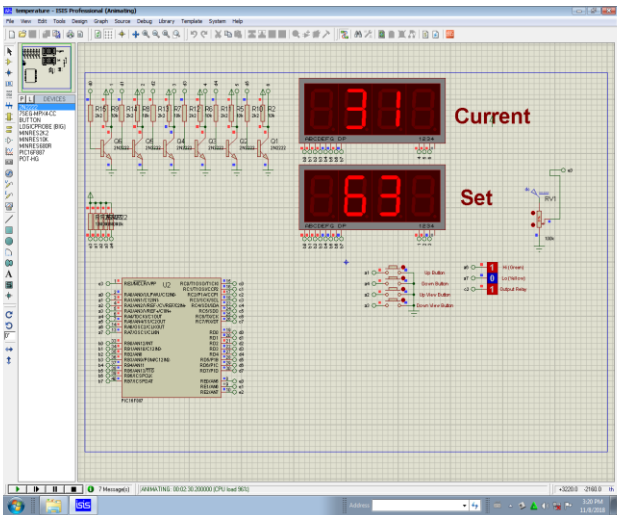


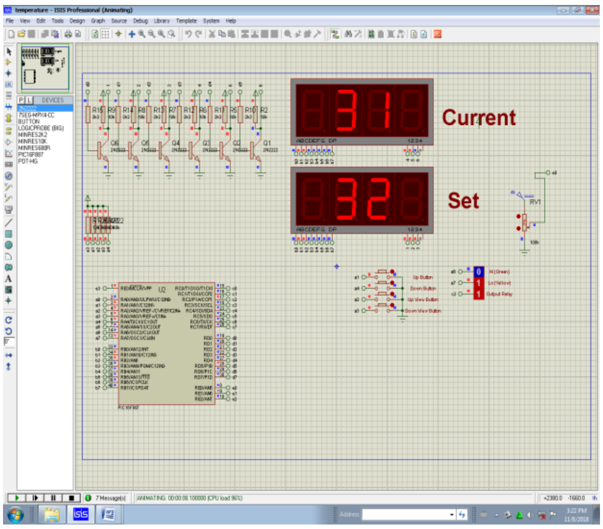
Figure3. Schematic diagram of the automatic temperature control system

In this circuit diagram PIC 16F887 microcontroller is the main component which is used for controlling other devices. Thermocouple is used as a temperature sensor for determine the temperature of the electric heater. The output voltage of the thermocouple temperature sensor is applied to the analog input RE0 of the PIC 16F887microcontroller IC via 100 kΩ potentiometer. The microcontroller would read these voltages and convert them to 10-bit number where 0V is 0 and 5V is 1024. I.e. a reading of 204.8 per volt or a resolution of $^{1}/_{204.8}$ i.e, 1 bit is 4.882812 mV.

Different temperature measurement and corresponding analog input voltage is shown below. Current and setting temperature is displayed on the Two 3-digit seven segment LEDs display.

- 30°C gave a voltage reading of 314.6 mV.
- 40°C gave a reading of 414 mV.
- 50°C gave a reading of 516.6 mV.
- 60°C gave a reading of 617.5 mV.
- 70°C gave a reading of 715.8 mV.
- 0°C gave a reading of 816 mV[





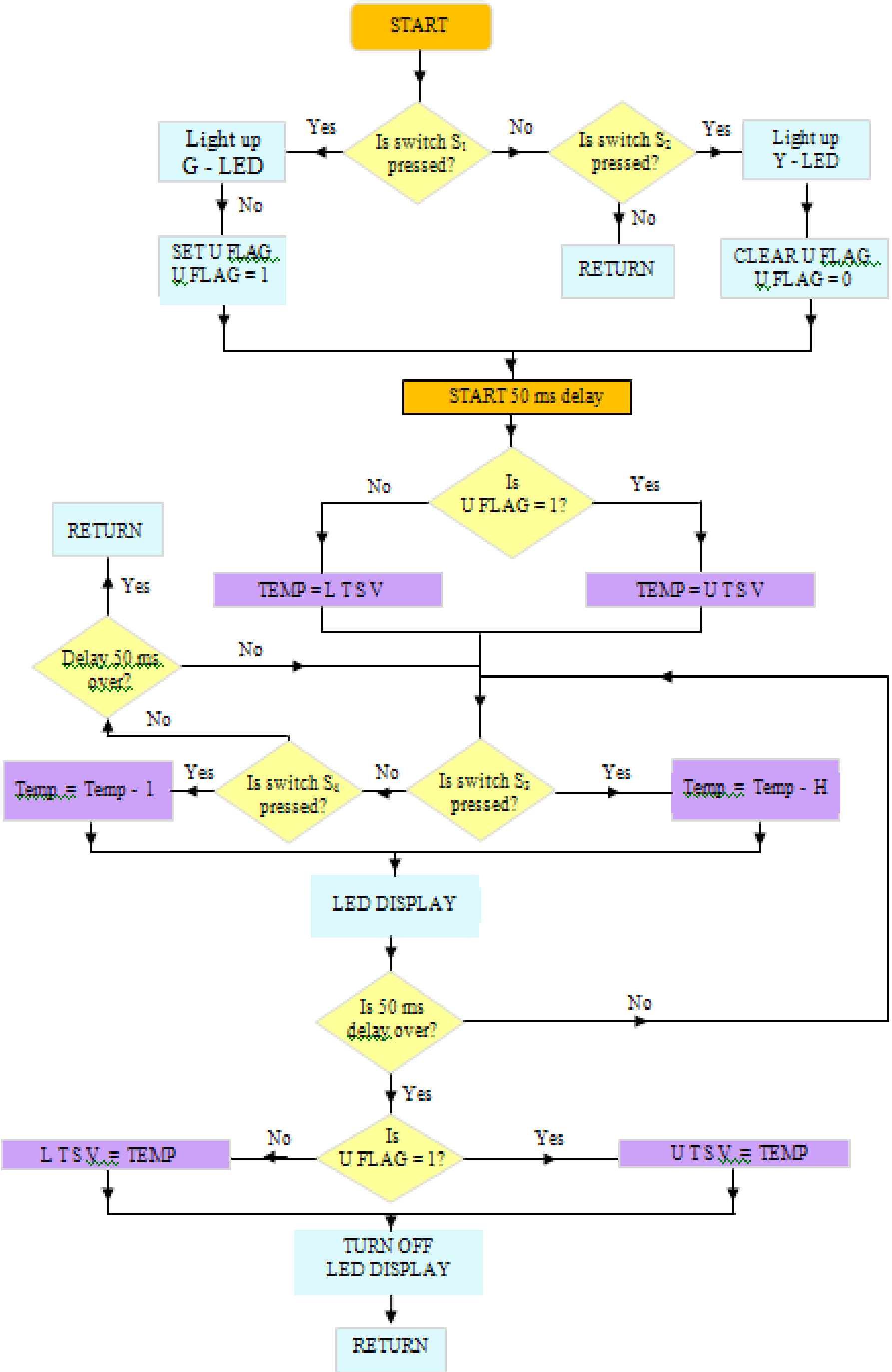
8 (a) Current and upper limit temperature. (b) Current and lower limit temperature.

Figure 4. The window of Proteus simulation for program execution

Figure 5. Hardware setup for automatic temperature control system

4.2 Software Design

The program flow chart of the proposed automatic temperature control system has been shown in Figure 6 which explains the whole software design procedures. The program is written in C language in the notepad and then saved with the file extension **.**C. The C program is converted into machine code (HEX code) by using MPASM assembler. After converting the HEX code, MPLAB simulation is essentially needed to execute properly for the source code. The window of simulation on program execution is shown in figure 7. The HEX code is downloaded into the MCU by the use of the programmer circuit.


START
Is switch S_1 pressed?
Yes
Light up G - LED
No
SET U FLAG U FLAG = 1
No
Is switch S_2 pressed?
Yes
Light up Y - LED
No
RETURN
CLEAR U FLAG U FLAG = 0
START 50 ms delay
Is U FLAG = 1?
No
Yes
TEMP = L T S V
TEMP = U T S V
RETURN
Yes
Delay 50 ms over?
No
No
Is switch S_4 pressed?
Yes
Temp = Temp - 1
No
Is switch S_3 pressed?
Yes
Temp = Temp - H
LED DISPLAY
Is 50 ms delay over?
No
Yes
Is U FLAG = 1?
No
L T S V = TEMP
Yes
U T S V = TEMP
TURN OFF LED DISPLAY
RETURN

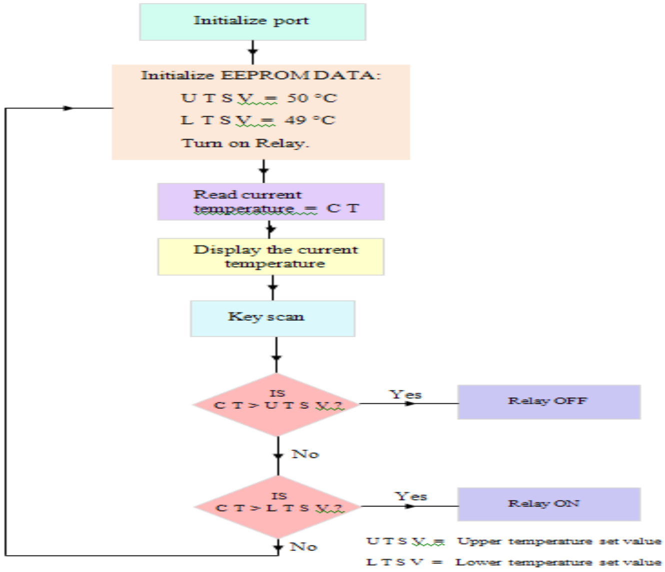


Figure 6. Program flow chart of the proposed automatic temperature control system

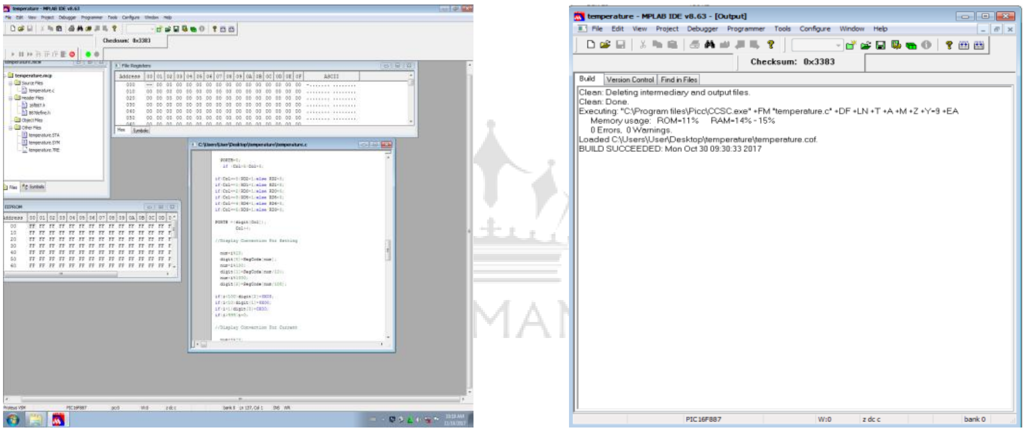


Figure 7. Window of simulation on program execution

5 RESULTS AND CONCLUSION

Microcontroller based automatic temperature control system is a simple and useful circuit which can be used to control the temperature above and below of a preset value using mid-range PIC 16F887 microcontroller IC. In this system it has internally ADC, so it needs not go to external interfacing ADC. Thermocouple is used as temperature sensor.

The actual temperature and set value of temperature were getting displayed on the Two 3-digit seven segment LEDs display and the set temperature was found changing with the help of preset buttons. Output was verified by setting the temperature at different levels and it was found that the heater (bulb) turn on and off when the device crosses the set value.

As explained the circuit can be made useful in practical area where the circuit can be connected to a device whose temperature has to be controlled at a particular limit say a water tank with a heater whose temperature can be set to a particular value. The program memory word used for the microcontroller based temperature control system is 1024. The higher version of PIC microcontroller such as 18F452 can also be used by changing the file registers.

The constructed microcontroller based temperature control system circuit can be used to control the various fields of temperature control equipments. In conclusion, the constructed microcontroller based temperature control system circuit meets the requirements satisfactorily for use in temperature control applications.

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