AUTOMATIC ROOM TEMPERATURE CONTROL WITH SECURITY SYSTEM

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Signature : ________________________

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Date : 12 MAY 2009

Specially dedicated to

My beloved parent

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Assalamualaikum.

ABSTRACT

Temperature control is a process to maintain the temperature at certain level. This process is commonly use in all area of the world. Recently in globalization era, this process become important element because there are many applications in daily life involves this process especially server room and green house. Server room works continuously in 24 hours every day. During the process, server room needs to be monitored frequently in order to ensure its functional and efficiency especially on temperature. It is important to study the level of temperature recommended in server room. This matter must be considered to make sure no disturbance occur in server room due to unstable temperature. Automatic temperature control referred as the best method in any application by controlling the temperature automatically. This method shows significant improvement in temperature control as the process is functioning without needed support from the human to control all the process. The result obtain from the process shows the temperature is controlled effectively and more accurate. In addition, this finding makes human works become easy and system that automatically controlled and function will be developed.

ABSTRAK

Kawalan suhu adalah proses untuk mengekalkan suhu pada paras yang tertentu. Proses ini secara umumnya digunakan di seluruh tempat seluruh dunia. Baru-baru ini di era globalisasi, proses ini menjadi unsur yang penting disebabkan banyak aplikasi dalam kehidupan seharian melibatkan proses ini khususnya di bilik server dan rumah hijau. Bilik server bekerja secara berterusan selama 24 jam setiap hari. Semasa proses itu berjalan, bilik server perlu dipantau secara kerap untuk memastikan fungsi dan keberkesanannya khususnya terhadap suhu. Adalah satu kepentingan untuk meneliti paras suhu yang disyorkan dalam bilik server. Perkara ini mesti di ambil kira untuk memastikan tiada gangguan berlaku dalam bilik server disebabkan suhu yang tidak stabil. Kawalan suhu secara automatik dirujuk sebagai kaedah paling terbaik dalam mana-mana aplikasi dengan mengawal suhu secara automatik. Kaedah ini telah menunjukkan pembaikan yang ketara dalam kawalan suhu disebabkan proses ini berfungsi tanpa memerlukan sokongan manusia untuk mengawal semua proses. Keputusan yang terhasil daripada proses tersebut menunjukkan suhu dikawal secara berkesan dan lebih tepat. Tambahan lagi, penemuan ini membuatkan kerja manusia menjadi mudah dan sistem yang mengawal dan berfungsi secara automatik akan terhasil.

LIST OF SYMBOL

°C	-	degree Celcius
A	-	ampere
mA	-	miliampere
μF	-	microfarad
Ω	-	ohm

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, in globalization era there are always the foundation of the new technologies features every year. Automatic temperature control system become the most popular features which rapidly gaining its popularity due to its importance to certain applications. This system utilizes in a room that lack of air conditioning system such as in server room and green house. The system is designed that is supposed to monitor the temperature inside a server room. In server room, the temperature is always high and unstable and human will not able to control the temperature manually. The automatic system required to control the temperature within the server room is measured by using a temperature sensor. When the current temperature is below the lower limit of the desired if it is in the first upper limit 25°C to 40°C, the server room is cooled using a fan. When the current temperature is within the desired range, no control action is needed. The current temperature of the room must be continuously displayed on the LCD. In addition the controller should use LEDs to indicate the current state of temperature in the server room.

1.2 Objective

1. To implement automatic room temperature control based on temperature sensor.
2. To implement the security system at the room based on password requirement to unlock the door.

1.3 Project Scopes

There are three scopes in this project:

1. Temperature sensor monitoring the recent value of temperature within the range
2. Fan functioning at certain level of temperature
3. Password requirement to unlock the door

1.4 Research Methodology

i) Literature review to understand the concept and functional of the project.
ii) Understand the whole system of hardware and software in sequences.
iii) Design the circuit and build the programming.
iv) Testing the system functional.
v) Combining the both hardware and software system.

Design step of work methodology can be simplified as shown in Figure 1.1

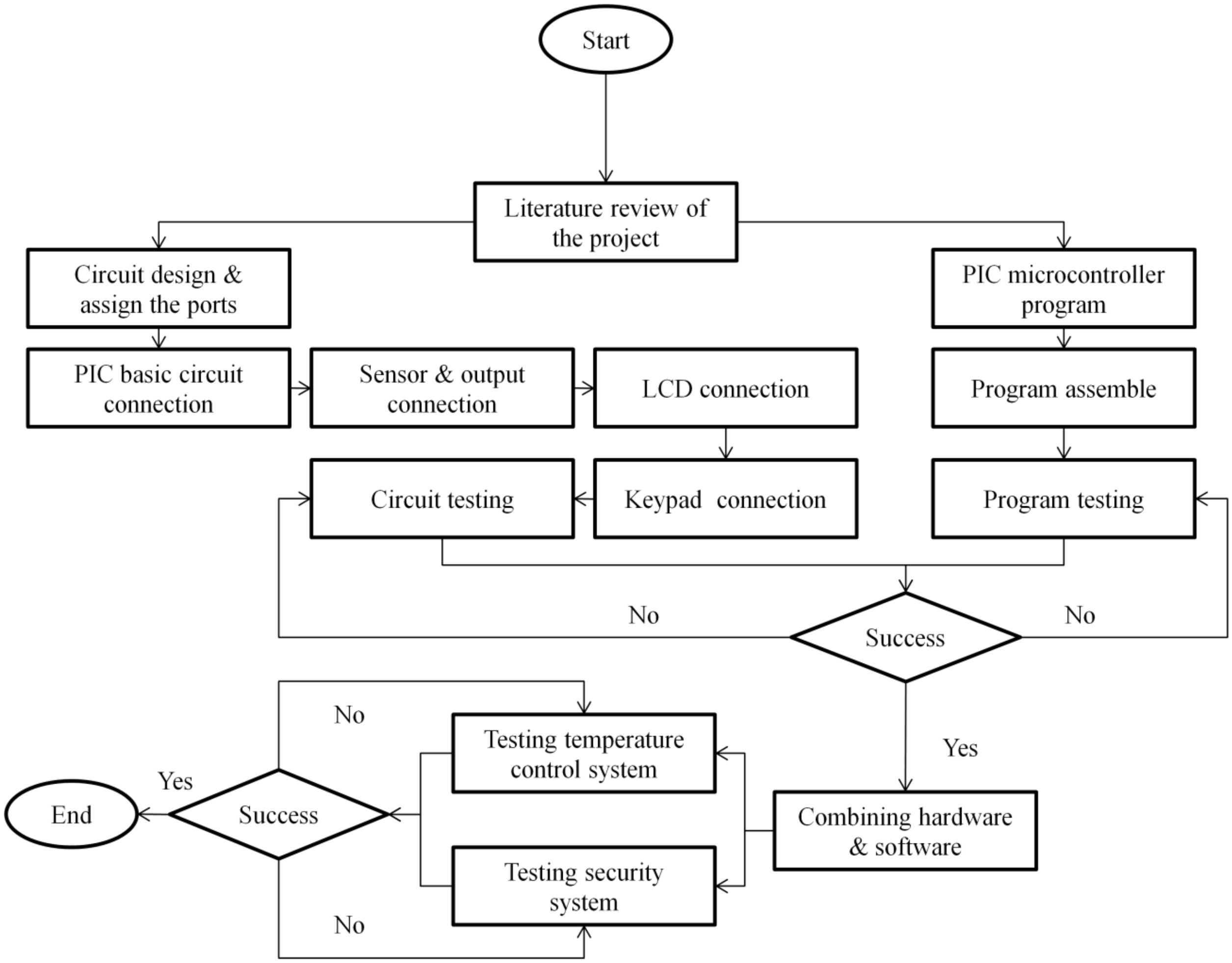

Figure 1.1: Design Flowcharts.

1.5 Thesis Outline

This thesis contains 6 chapters and they are outlined as below:

Chapter 1 explains the introduction that includes concept of temperature control system and security systems. It also outlines the objectives and scopes of this system.

Chapter 2 describes the literature review from recent issue and gives a brief review about the past project.

Chapter 3 provides description and discussion on the design of the hardware of each module in the systems. The module consists of microcontroller board, sensor, and LCD displays driver circuit and output devices.

Chapter 4 explains the development of the software and system operation. This chapter also includes the flowchart of the system.

Chapter 5 presents testing and results that conducted to each module. This chapter includes the integrated system testing which all the modules are combined.

Chapter 6 summarizes the overall conclusion for this thesis and a few future recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will review about the server room and available projects on this topic.

2.2 Server Room Overview

A server room is a room that houses mainly computer servers. The term is generally used for smaller arrangements of servers. Larger groups of servers are housed in data centers. Server rooms usually contain headless computers connected remotely via KVM switch, VNC, or remote desktop. [1]

Environmental monitoring is essential in the server rooms and data centers. Environmental conditions have a huge impact on how reliable and long lived the servers, switches and routers will be. Bad environmental conditions can reduce the life of components, decrease reliability, and cause us untold problems and expense.

Computer equipment ages faster when it gets hot. In fact equipment manufacturers use this property to help eliminate faulty components batches are ’baked’ to test for failing units. The idea is that if a component survives this process then it stands a good chance of being reliable in service. In general computers operate more reliably and have a longer life in cooler conditions. The effects of prolonged running at high temperatures can be unpredictable and are not always characterized by catastrophic failures.

Computer and networking equipment is designed to operate within a fairly narrow temperature range. To ensure reliable operation and the longest possible life from components we need to ensure that the temperature stays within that band.

Purpose built server rooms are well insulated for fire precaution reasons and air conditioning is essential. In many companies however the maintenance of the air conditioning is separate from the running of the servers. If the air conditioning fails we might not be the first to know about it. We may even be the last. [2]

General recommendations suggest that temperature range in server room should not go below 10°C (50°F) or above 28°C (82°F). Although this seems a wide range these are the extremes and it is far more common to keep the ambient temperature around 20-21°C (68-71°F). For a variety of reasons this can sometimes be a tall order. [3]

2.3 Temperature Control System

This project use PIC16F876A to control NPN power transistor (BD135) further drive DC brushless fans, LEDs and buzzer when the certain temperature was detected. The value of temperature always displayed on a LCD screen. This project uses two temperature sensors that placed at different area. This means that temperature can be measured at different place. [4]

2.4 Door Lock Security

This project will use PIC16F877A, LCD screen and keypad to develop a password door security system. The system will activate the relay and buzzer if the password is inserted. The relay controls the door while the buzzer as indicator for incorrect password. The door used is magnetic door which is automatically open and close depends to the relay. [5]

CHAPTER 3

SYSTEM DESIGN

3.1 Introduction

The block diagram in Figure 2.1 shows that how the systems operate in a server room. There are two separate systems which are temperature control systems and security system. For temperature control system, temperature sensor that is placed in the server room detects the current temperature and display the value on the LCD. PIC microcontroller will read data from temperature sensor which is in output voltage. The system will operate in three different conditions depending on the range of temperature. If the current value of temperature reaches higher than desired value, the fan will start functioning and LED indicator for high temperature will on. Then, if the current temperature reaches at the desired value, the fan stop functioning and LED indicator for normal state temperature will on. Finally, if the current temperature reaches lower than desired value, fan will not functioning and LED indicator for cold temperature will on. Any changes of temperature in the room are continuously displayed on the LCD. In addition the LEDs are used to indicate the current state and range of temperature in the server room.

Another features included is security system. The security system used is the door lock security. This means that user have to insert the password to unlock the door in order to enter the room. If the correct password inserted, the door will unlock but if incorrect password inserted, door still lock and buzzer will on. The password that inserted by the user will displayed on LCD. The temperature control system and security system is not interact each other. This means that if one of the systems fails, the other system still functioning without any problem.

The hardware design consists of PIC microcontroller circuit, sensory input circuit, driver circuit, LCD display module, LEDs and output circuit. The system board is designed using Bootstrap Mode connection due to the factor of size and cost of the project.

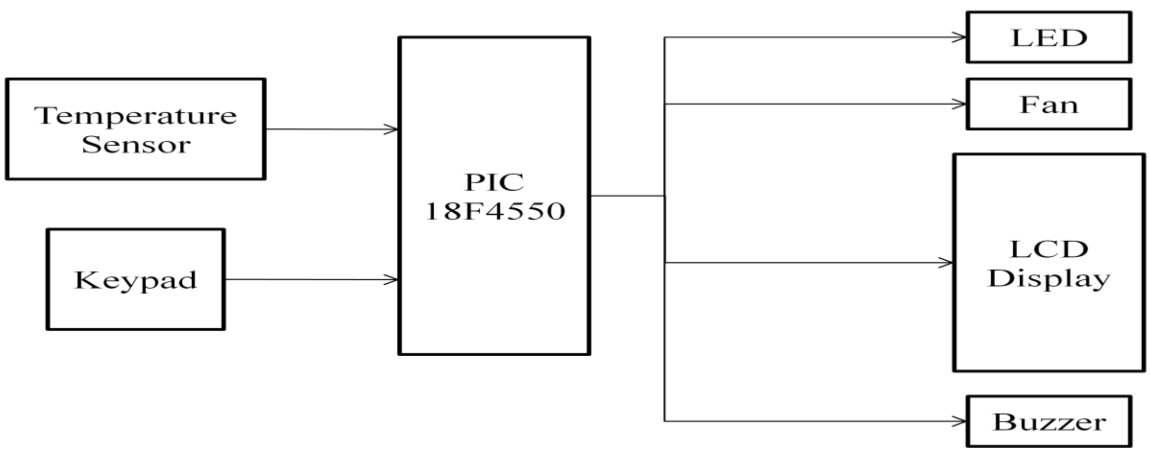

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Figure 3.1: Block diagram of the project

3.2 Main Components of the Project

In this project there are several components included as each of them have their specific function and task. These components are selected based on circuit reliability, function ability, and costs.

3.2.1 PIC Microcontroller

The microcontroller selected is the Microchip PIC18F4550 because of its ease of use, built in timers, and has many digital inputs and outputs. To avoid extra costs, this model is most basic that meets all of the design criteria. It is also a fairly new model so it should be available for year to come. **S**o the PIC18F4550 was the best choice available. The microcontroller is used to control the whole operation of the system. [1]

The figure 3.2 shows the pin assignment of PIC18F4550. This type of microcontroller consists of 40 I/O pins.

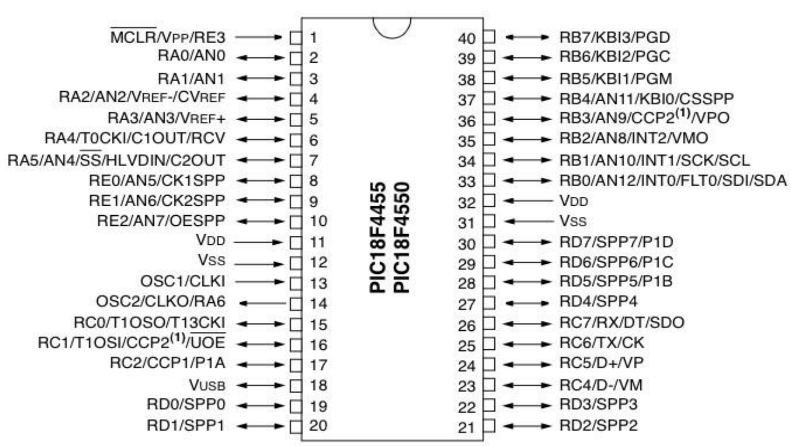

Figure 3.2: PIC18F4550 schematic diagram

3.2.2 Temperature sensor LM35DZ

Temperature sensor LM35DZ is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature in degree Celsius (^{o}C). [6]

Figure 3.3: LM35

3.2.3 LCD Display

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.

The type of LCD used is alphanumeric with 2 lines of 16 characters as shown in figure 3.4.

Figure 3.4: LCD Display

Table 3.1 shows the pin connection of LCD to PIC microcontroller.

Table 3.1: LCD pin connection

Pin	**Name**	**Pin function**	**Connection**
1	VSS	Ground	GND
2	VCC	Positive supply for LCD	5V
3	VEE	Contrast adjust	Connected to a preset for contrast adjusting
4	RS	Select register, select instruction or data register	RD2
5	R/W	Select read or write	GND
6	E	Start data read or write	RD3
7	DB0	Data bus pin	RB0
8	DB1	Data bus pin	RB1
9	DB2	Data bus pin	RB2
10	DB3	Data bus pin	RB3
11	DB4	Data bus pin	RB4
12	DB5	Data bus pin	RB5
13	DB6	Data bus pin	RB6
14	DB7	Data bus pin	RB7
15	LED+	Backlight positive input	5V
16	LED-	Backlight negative input	GND

3.2.4 Keypad

The features of 4x4 keypad used where users have to key in the numbers or alphabet and the messages displayed on the LCD. The keypad only has keys labeled 0-9, * and #, and A-D. In this project, keypad is used to insert the password.

Figure 3.5 shows the figure of 4x4 keypad.

Figure 3.5: Keypad

3.2.5 Power Transistor

BD135 is used for controlling the DC fan with sufficient current. In this project, PIC cannot directly activate the DC fan because it has not enough current. NPN power transistor (BD139) is required to drive the fan, so that DC fan can be controlled by PIC.

The figure 3.6 shows the schematic diagram of BD135.

PINNING

PIN	DESCRIPTION
1	emitter
2	collector, connected to metal part of mounting surface
3	base

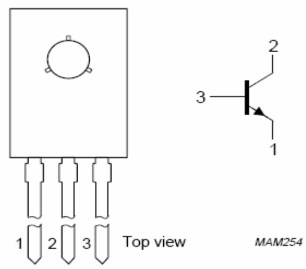

Fig.1 Simplified outline (TO-126; SOT32) and symbol.

Figure 3.6: BD135 schematic diagram

3.2.6 DC Fan

DC Fan is a 5V brushless fan that acts as the cooling system in this project. It will function if the temperature is high.

3.2.7 Buzzer

Buzzer act as indicator that give the signal through the sound produced as output. In this project, buzzer use to give warning signal for incorrect password.

3.2.8 LED

Three LEDs are used as indicator of current state of temperature. The LED's will represent in different color so that it is easier to recognize the range of temperature at different level.

3.3 PIC Microcontroller System Board

PIC Microcontroller system board module consists of power circuit and clock circuit. These circuits are the most important parts that support the basic operation of PIC microcontroller. One LED included as the indicator to make sure that PIC microcontroller is supplied and power up. Figure 3.7 shows the schematic diagram for PIC microcontroller system board circuit.

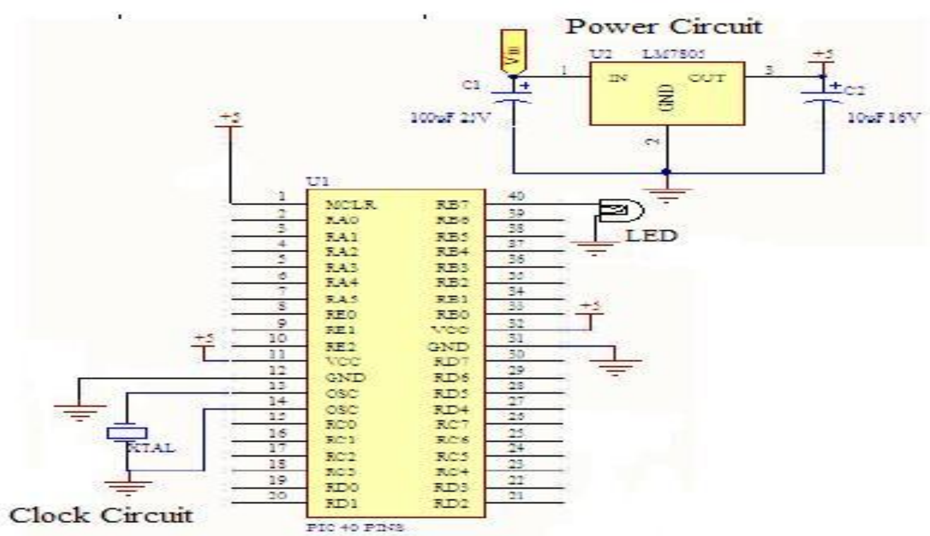

Figure 3.7: PIC Microcontroller System Board Circuit

3.3.1 Power Circuit

A voltage regulator is used to regulate the output voltage at 5V constantly throughout the whole circuit. This is important to prevent any damage on the components especially microcontroller from high load voltage. In this project, voltage regulator LM7805 is used to regulate 5V voltage. Figure 3.8 shows the schematic diagram for voltage regulator.

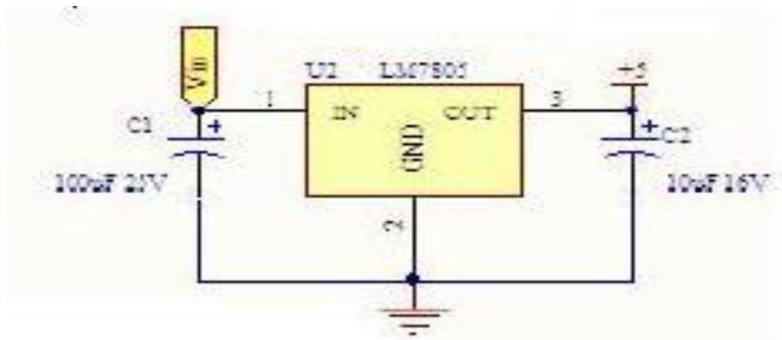

Figure 3.8: Power Circuit

3.3.2 Clock Circuit

In order to provide clock to the microcontroller system, a 20MHz crystal is used. The crystal is connected to the pin 13 and 14 at the PIC microcontroller. This crystal can give effects on how fast the programming is read by the PIC microcontroller. Figure 3.9 shows the schematic diagram of clock circuit.

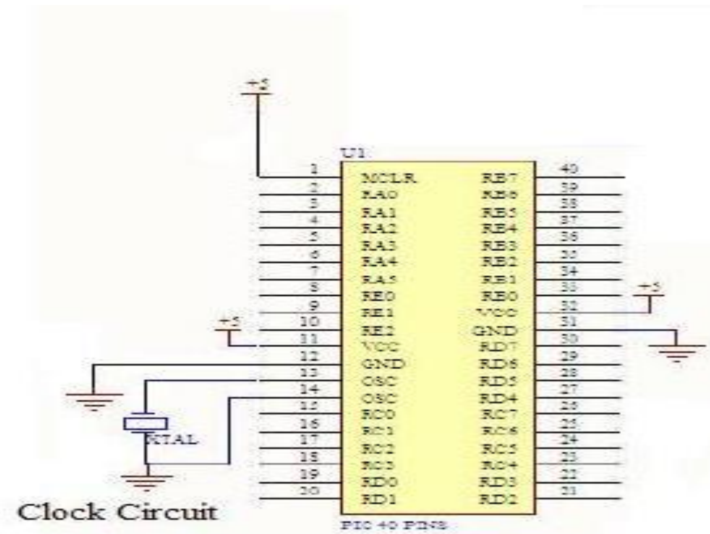

Figure 3.9: Clock Circuit

3.3 Temperature sensor circuit

The LM35DZ is functioning from the output voltage produced by the sensor. This sensor has capacitor 0.1μF that is connected to output and ground pin out to reduce electrical noise that occurs during measurement process of the sensor. Resistor of 100Ω is connected to input voltage of the sensor to control and avoid from high current. The output voltage produced is proportional to the value of temperature in degree Celsius. This data will be converted to byte value by the PIC programming. Figure 3.10 indicates the schematic diagram of temperature sensor circuit.

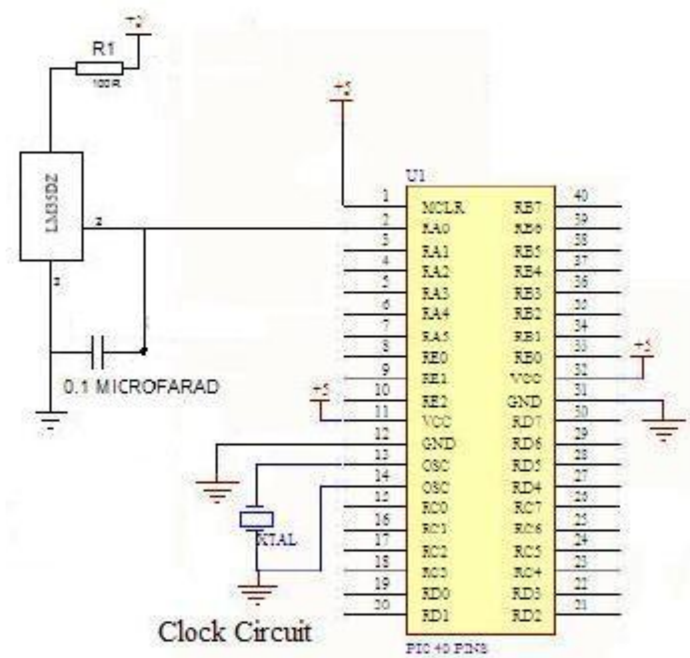

Figure 3.10: Temperature Sensor LM35 Circuit

3.4 LCD Display circuit

JHD 162 series is chosen as LCD display in this project. A simplified circuit is shown in Figure 3.11. Register Select pin (RS) is connected to PD2. It is used to determine if the operation is intended as a command or data. Similarly, Read/Write pin (R/W) is connected to ground and PD3 of microcontroller is connected to Enable pin (E). The LCD module is wired for a 8 bit mode which DB0-DB7 are connected to port B.

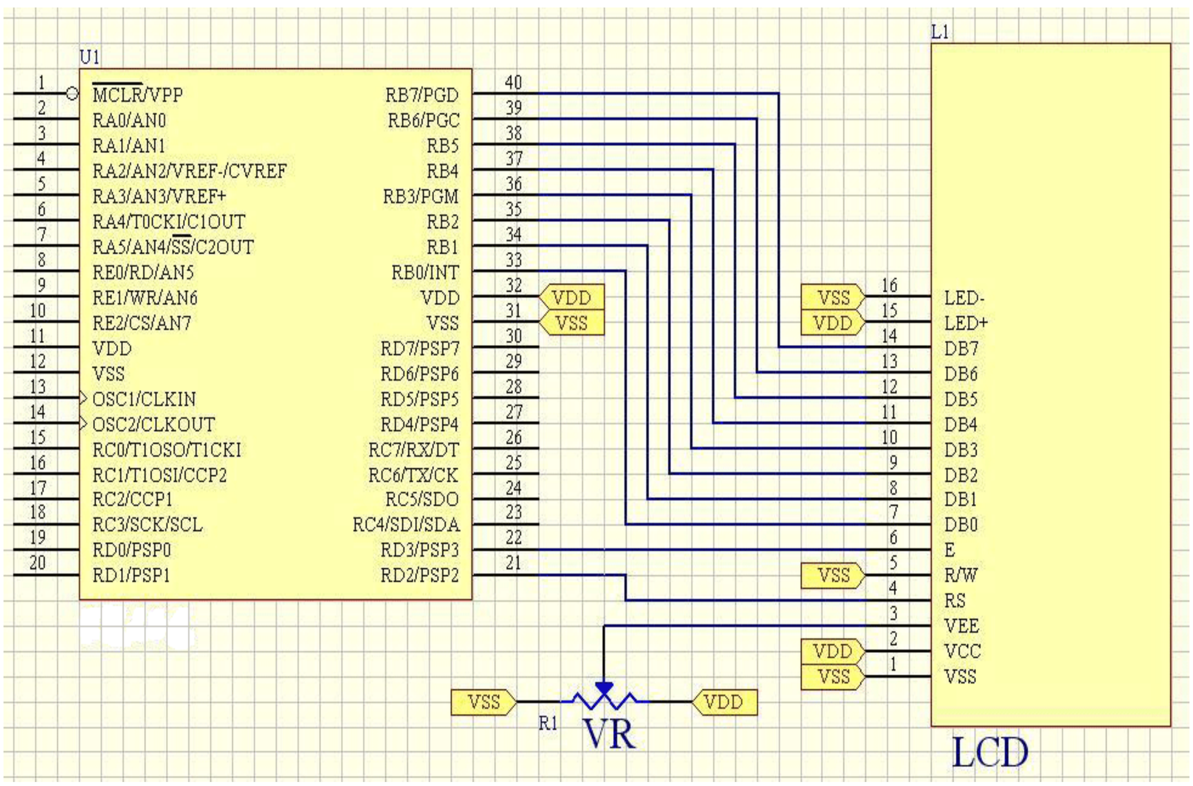

Figure 3.11: LCD Circuit

3.5 LED and Buzzer

LEDs are included as an indicator to show the current state of temperature in the server room. Three different colours of LEDs such as red, yellow and green are used. Each of them represent to indicate specified range where the temperature. For temperature that higher than 35°C, red LED is turned on. For temperature that within the range of 20°C until 35°C, green LED is turned on. For temperature that below than 20°C, yellow LED is turned on.

Buzzer is included as an indicator to show the signal warning. It will activate if user inserted incorrect password but will not activate if correct password inserted.

CHAPTER 4

SOFTWARE DEVELOPMENT

4.1 Introduction

Microcode Studio software is used to develop the program for this project. Program is written in basic language, and then it is compiled to make sure there is no error occurred in the program. The program will be written into PIC microcontroller by using PIC burner. The PIC microcontroller must be inserted into the PIC burner that is communicating with PC as shown in Figure 4.1 and select the pin use for burning process. There are few steps to be done before the program is verified and programmed into the microcontroller by using PICKit 2 Programmer.

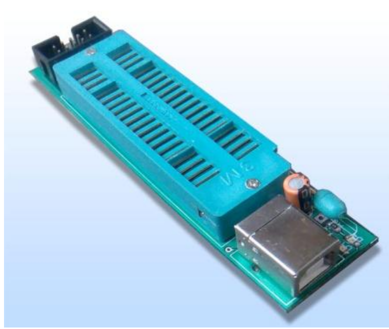

Figure 4.1: PIC burner

4.2 Steps in programming the PIC microcontroller

There are a few important steps required to program the PIC microcontroller. Two software are used for completing this task. Microcode Studio application is used for creating and compile the program while PICKit 2 Programmer application is used to write the program into PIC microcontroller. The important steps included in this process are:

1. Run Microcode Studio application and load the program. Select the type of PIC microcontroller. This is important to make sure the program is suitable with the PIC microcontroller used.

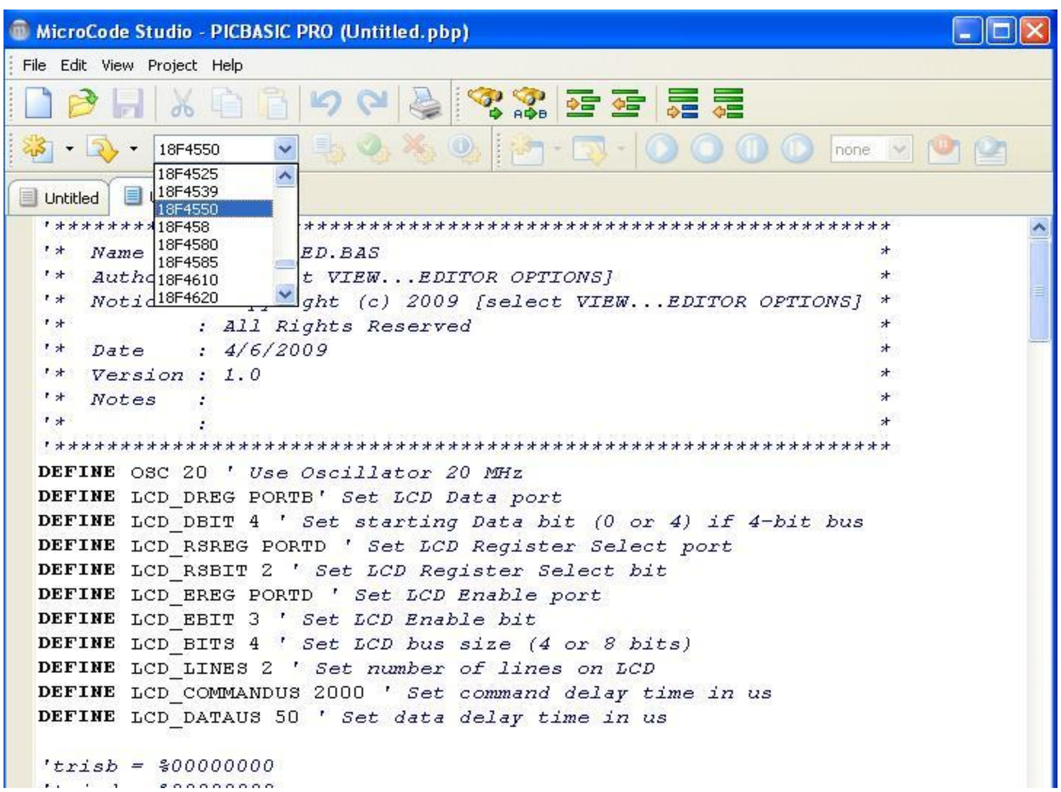

Figure 4.2: Select the type of PIC microcontroller used

2. Compile the program. This is to ensure no error occurred in the program.

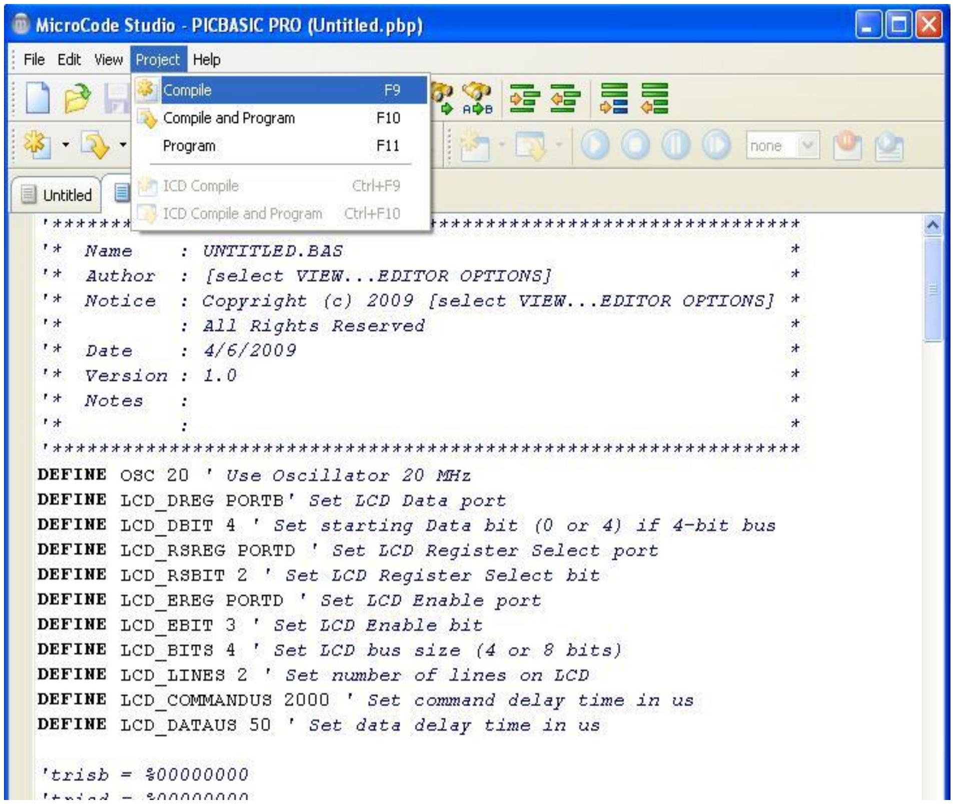

Figure 4.3: Compile the program

3. Run PICKit 2 Programmer application. Select check communication. This is to ensure the PIC burner is connected to the PC.

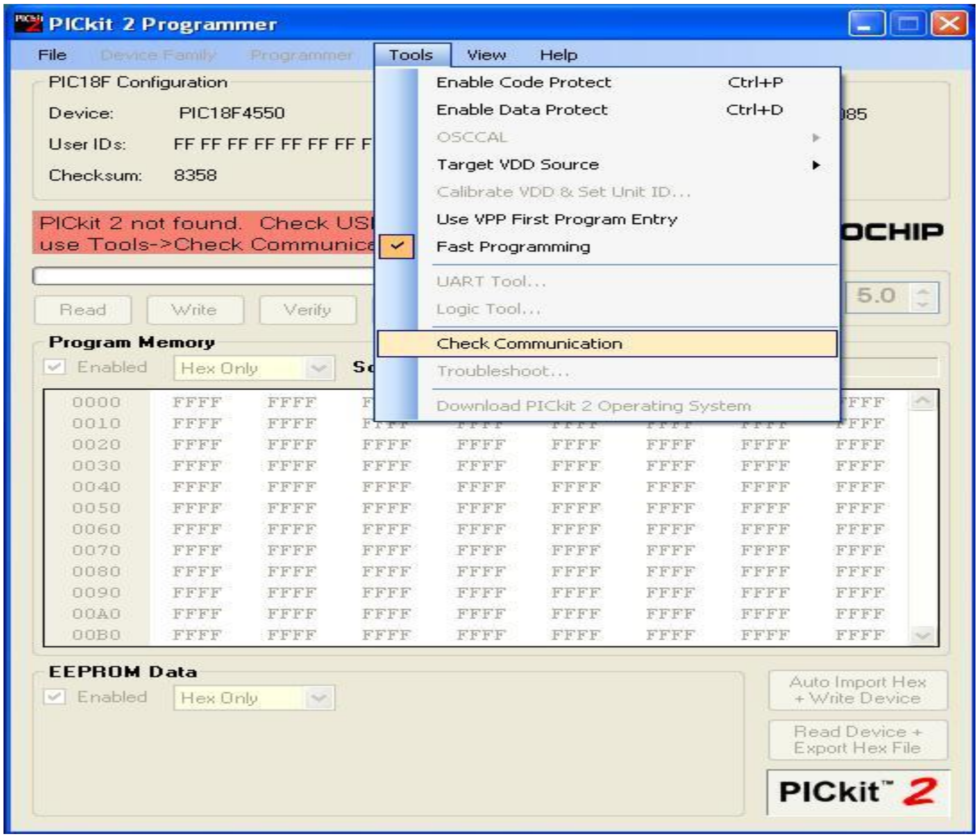

Figure 4.4: Check communication between PC and PIC burner

4. Select erase to clear the PIC microcontroller. This is to ensure there is no other program in PIC microcontroller and avoid the error when writing the program into PIC microcontroller.

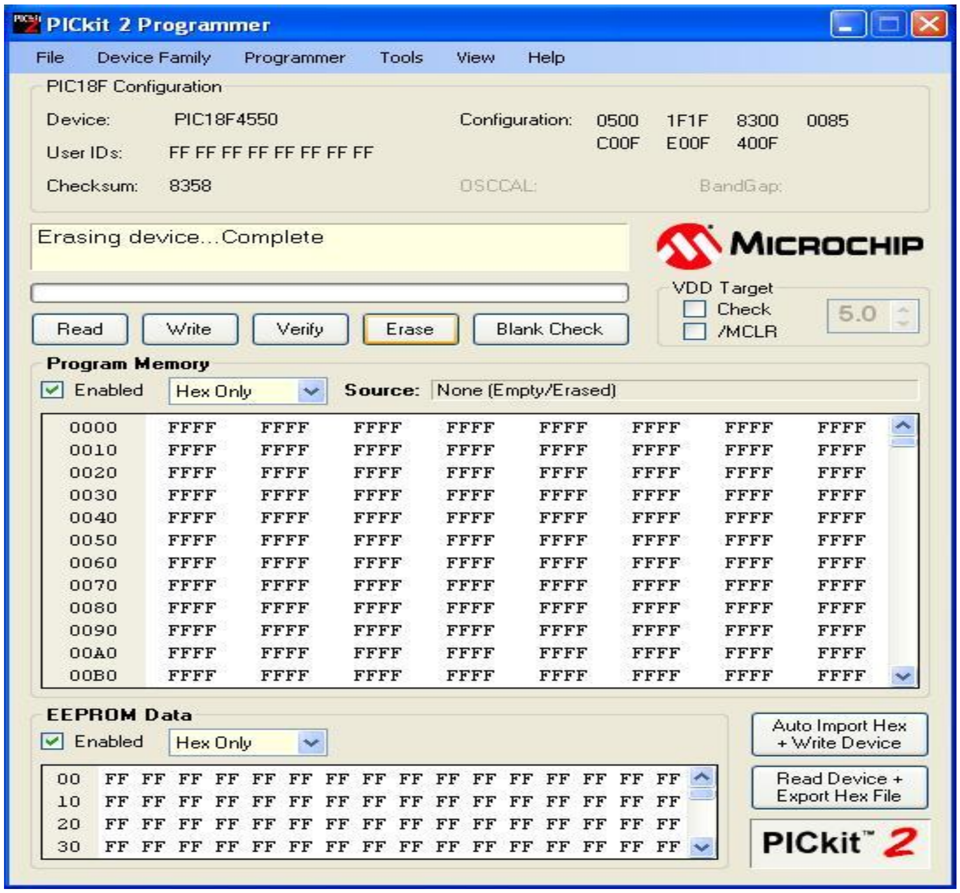

Figure 4.5: Erasing any of the programs in the PIC microcontroller

5. Load the program and select write to burn the program into PIC microcontroller. The PIC microcontroller is programmed.

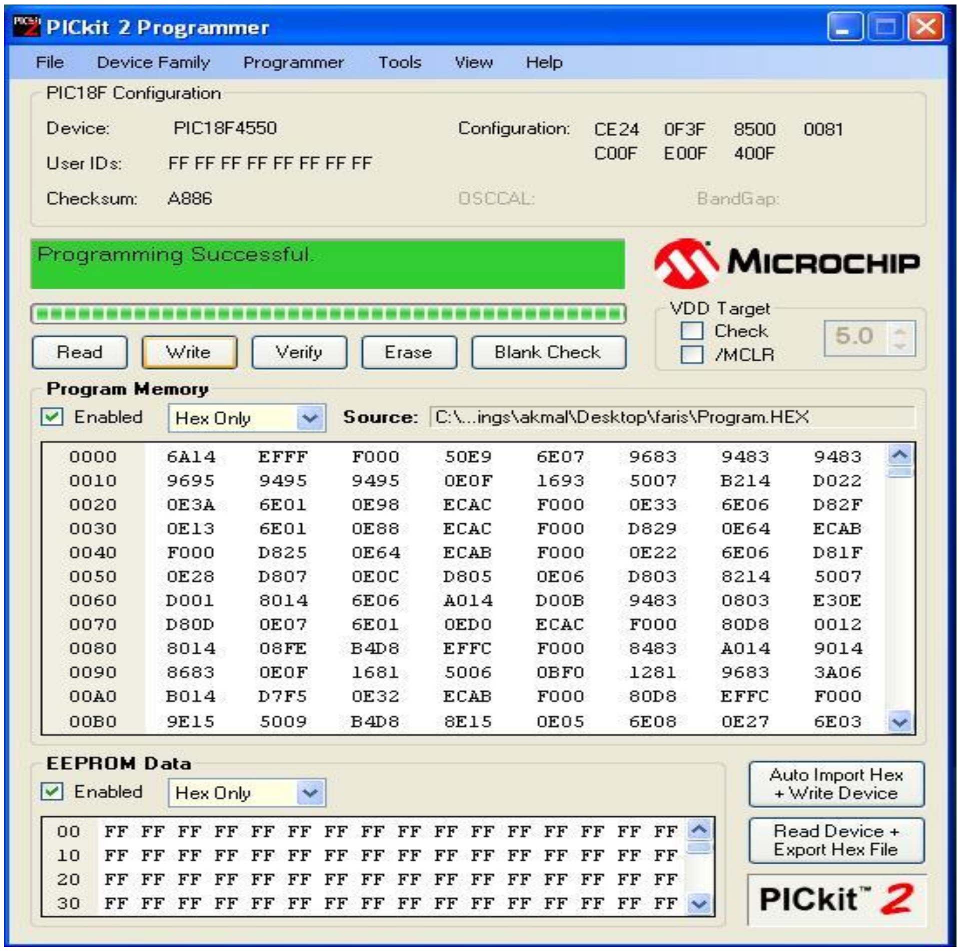

Figure 4.6: Writing the program into PIC microcontroller success

4.3 Temperature Control System Software Development

Once the system is powered up, temperature is detected by temperature sensor LM35 respectively. The values are sent to PIC microcontroller for manipulation purpose. The current temperature values are represented at output voltage of LM35. The output voltage is in analog form and the value will be converted to byte value.

$$\text{Byte value} = \text{Output voltage} \times 2\text{^}8 \text{ bits/5V}$$

For example if the output voltage of LM35 is 0.32V at 30°C, the byte value that represent for the temperature at 30°C is:

$$\begin{aligned} \text{Byte value} &= 0.32 \times 256/5 \\ &= 0.32 \times 51.2 \\ &= 16.38 \\ &= \mathbf{16} \end{aligned}$$

These conversions cause the value of temperature is represented in digital byte form. Each of byte values are used to represent temperature range which each these ranges is supposed to trigger output. The calculation of the byte value is not the process of analog digital conversion because this process will be done by PIC microcontroller. The byte value is used for representative value in programming due to programming can only execute the data in digital form. These values are also declared into decimal form to display them on LCD.

Figure 4.7 shows the software development of temperature control system

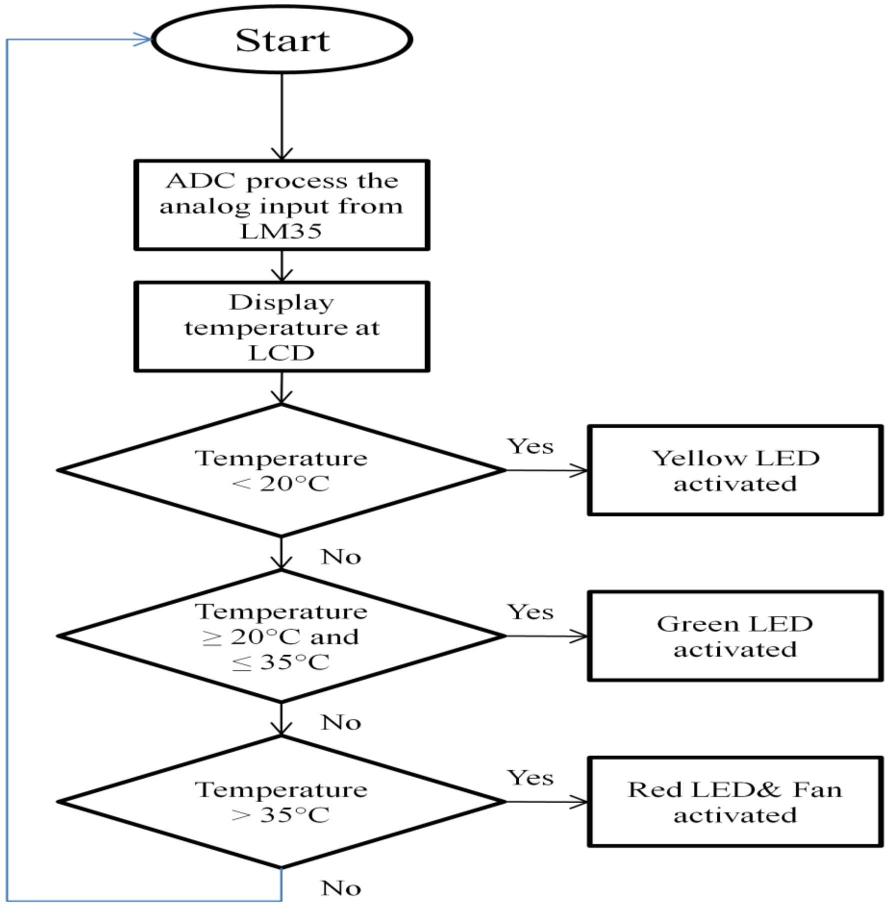

Figure 4.10: Flow Chart of Temperature Control System

CHAPTER 5

RESULT

5.1 Introduction

Extensive testing has been performed part by part on the developed system and the approach taken in executing the various tests are discussed in this chapter.

In developing temperature control system, various tests are conducted. The tests include input sensory module testing, PIC microcontroller board testing and LCD display test. These tests conducted to make sure all the systems part function well due to most of the part system are interact each other. Each module is integrated into a single system to produce a fully functioning temperature control system.

5.2 Flowchart of the whole system

The figure 5.1 shows the flowchart of result for the whole project. Since there are two different systems which are temperature control system and security system in this project, the results can be obtained from either system or both. This is because the two systems are not interacting each other.

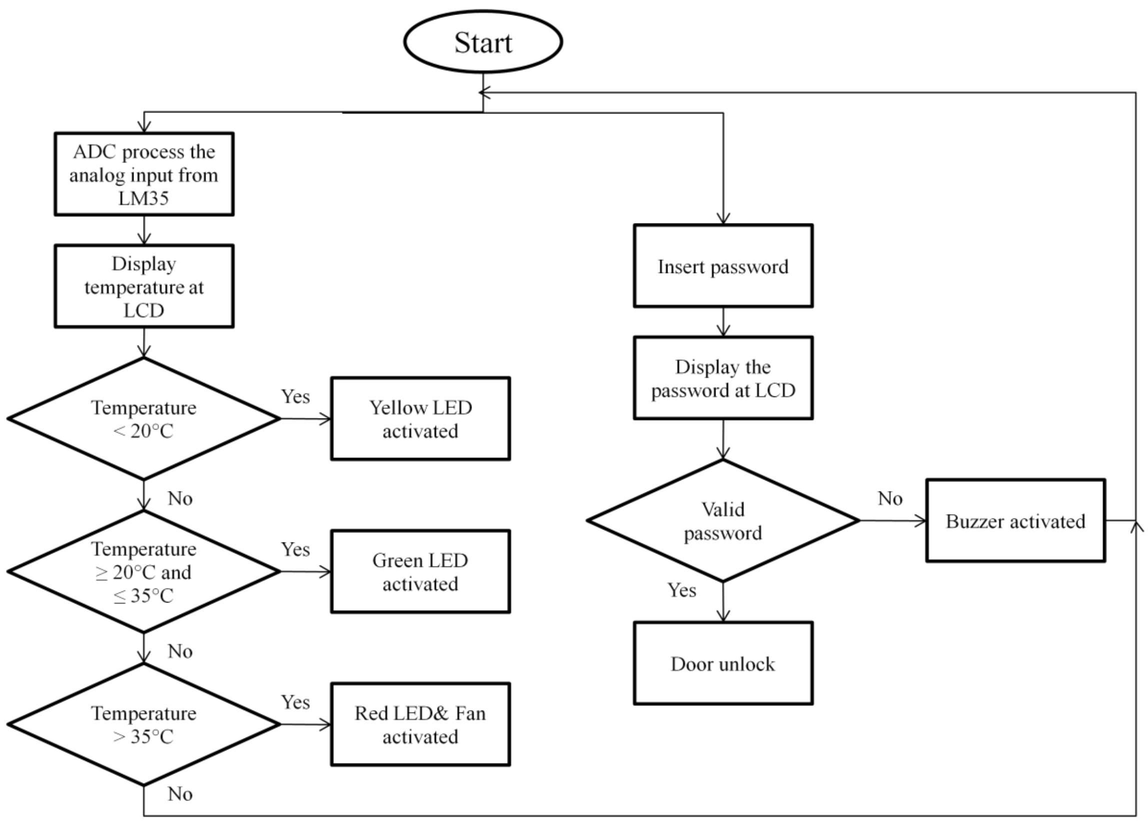

Figure 5.1: Flowchart for whole project operation

5.3 PIC Microcontroller Circuit Testing

Microcontroller system board is designed as shown in Figure 5.2.

A basic program as shown in Table 5.1 is compiled and programmed into the microcontroller. The purpose of this test is to ensure that PIC microcontroller can program the hardware and test its reliability. This test also can detect whether the basic PIC circuit functioning well. When the program is executed, a simple blinking LED display is produced and this verifies that PIC microcontroller circuit system is successfully designed.

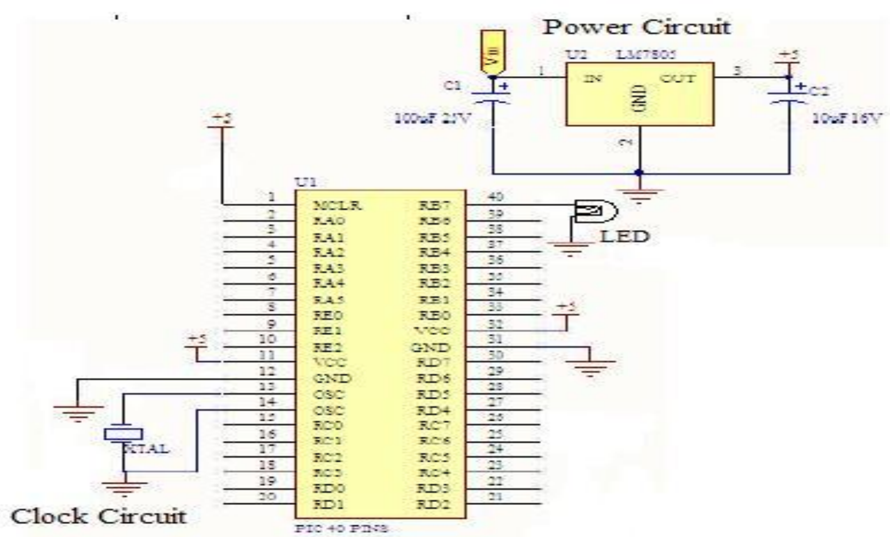

Figure 5.2: PIC microcontroller circuit testing

Table 5.1: LED Testing Program

```
DEFINE OSC 20
LED:
LOW       PORTB.7
PAUSE      500
HIGH      PORTB.7
PAUSE     500
GOTO      LED
```

5.4 LCD Module Testing

In order to test the LCD functionality, the circuit as shown in Figure 5.3 is connected. Then, a simple program to display your name on LCD as shown in Figure 5.4 is written and compiled. When the program is executed, the LCD will display your name. Therefore, it is concluded that LCD module testing is successfully completed and can be used for display purposes.

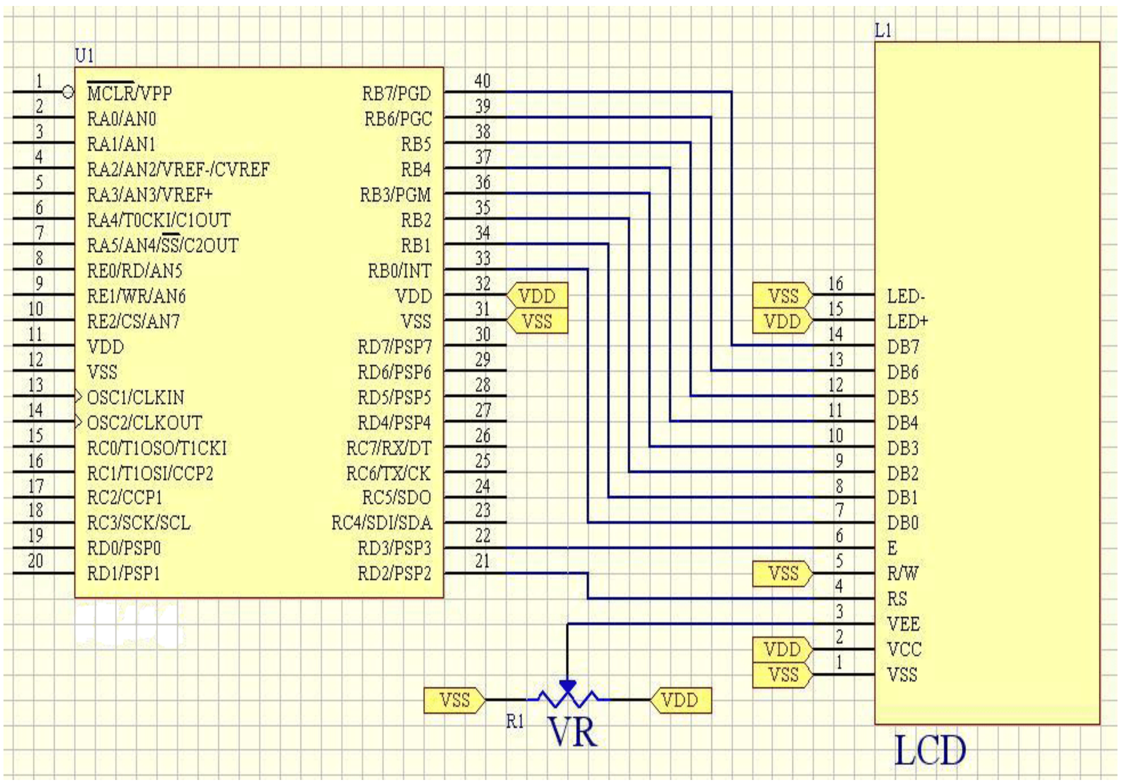

Figure 5.3: LCD connection diagram

Figure 5.4 shows the basic LCD display testing source code. This is to ensure that LCD is functioning well

```
'*  Name    : UNTITLED.BAS                                      *
'*  Author  : [select VIEW...EDITOR OPTIONS]                    *
'*  Notice  : Copyright (c) 2009 [select VIEW...EDITOR OPTIONS] *
'*          : All Rights Reserved                               *
'*  Date    : 4/5/2009                                          *
'*  Version : 1.0                                               *
'*  Notes   :                                                   *
'*          :                                                   *
'****************************************************************
DEFINE OSC 20 ' Use Oscillator 20 MHz
DEFINE LCD_DREG PORTB' Set LCD Data port
DEFINE LCD_DBIT 0 ' Set starting Data bit (0 or 4) if 4-bit bus
DEFINE LCD_RSREG PORTD ' Set LCD Register Select port
DEFINE LCD_RSBIT 2 ' Set LCD Register Select bit
DEFINE LCD_EREG PORTD ' Set LCD Enable port
DEFINE LCD_EBIT 3 ' Set LCD Enable bit
DEFINE LCD_BITS 8 ' Set LCD bus size (4 or 8 bits)
DEFINE LCD_LINES 2 ' Set number of lines on LCD
DEFINE LCD_COMMANDUS 2000 ' Set command delay time in us
DEFINE LCD_DATAUS 50 ' Set data delay time in us
Main:

    LCDOUT $FE,$02 ' Send Command To Clear Screen
    LCDOUT "Ahmad Faris"' Show Text on Line 1
    LCDOUT $FE,$C0 ' Set Cursor on Line 2
    LCDOUT "Zulkifli" ' Show Text on Line 2
    PAUSE 2000
    LCDOUT $FE,$01 ' Send Command To Clear Screen
    GOTO Main
    END
```

Figure 5.4: LCD testing code

5.4 Input Sensory Module Testing

A simple manual test is performed on temperature sensor LM35. Initially, output voltage of this sensor LM35 is measured by using a multimeter. In the same time, the current temperature value close to the sensor is measured by a thermometer. There are three tests done to detect the output voltage at different temperature. Firstly we measure the output voltage of the sensor at room temperature. Secondly, we measure the output voltage of the sensor at cold level with measuring the temperature of ice mixed with salt. This is the way to decrease the temperature. Finally, we measure the output voltage of the sensor at hot level with measuring the temperature by placing the sensor near a lit candle. This is the way to increase the temperature. The results that we can get from these tests are the output voltage decrease when temperature decreases and the output voltage increase when the temperature increases. This shows that output voltage of the sensor is proportional to the Celsius temperature. Hence, based on the experiment mentioned earlier, a conversion program is written to convert the output voltage of the sensor into byte value. The temperature is sensed by LM35 as shown in Figure 5.5. The internal A/D Converter in microcontroller converts the analogue data into digital form. This data is in output voltage which is converted to byte form. Then, it is converted again into centigrade scale through a required formula in the program. Next, the data is declared into decimal form in order to display the current temperature on LCD. When the program is executed, temperature will be sensed by the sensor and the values are being displayed on LCD.

5.5 Result of Output Voltage of LM35

Table 5.2 shows the output voltage of temperature sensor LM35 at certain temperature. All the output voltages of LM35 that are listed in the table are converted to byte value. However, the byte values which have point must be changed to integer. It is because PIC program can only read integer values. Then, a graph is sketched and any two points are used in calculation of linear equation (y = mx + c).

Table 5.2: Output Voltage of LM35

Temperature (°C)	Output Voltage (V)	Byte Value
0	0.10	5
20	0.22	11
30	0.32	16
40	0.45	23
50	0.60	31

Figure 5.5 shows the graph of temperature change with byte value

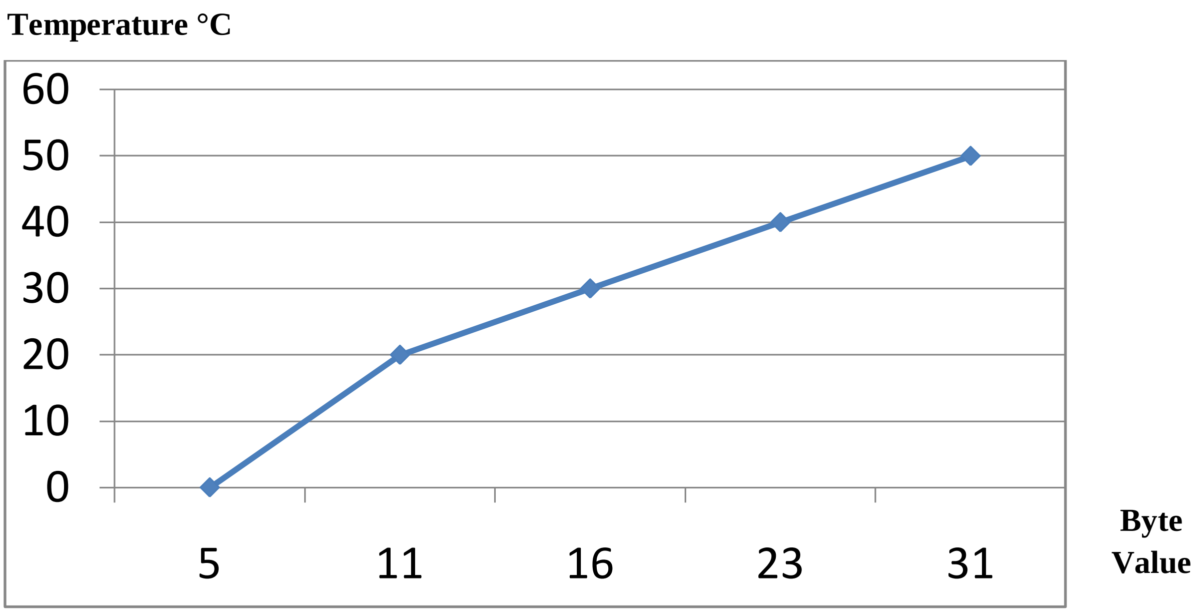

Figure 5.5: Graph temperature versus byte value

From the graph the linear equation $7y = 10x + 50$ is determined and must be included in the PIC program for LCD display. It will convert the byte value to centigrade scale of current temperature and when the temperature changes.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This project is not fully completed and all the objectives are not accomplished. The temperature control system is able to detect and control temperature in server room automatically but the LCD failed to display the value of temperature. This is due to hardware failure on LCD. When this failure occurs, the temperature value and password value inserted by the user will not be displayed on LCD.

This system is suitable to be used as temperature controller inside a server room when server room cooling system fails to operate properly or temperature range is out of normal. It should be a backup system to turn back undesired temperature range to normal range.

6.2 Problem Encounter

1. Small range temperature detection
   - The temperature sensor LM35 has high sensitivity but small range temperature detection. As a result, the sensor will only able to detect the temperature changes effectively at the range that is very close to the sensor

2. Sensor easy to damage
   - The temperature sensor LM35 can only operate in low current value only. It means that this sensor is easily damage and out of function if over current occurs in the temperature sensor circuit.

3. LCD error
   - The problem of LCD in this project is the LCD unable to display the value of temperature and password value. LCD is functioning as it has power up but it fail to display any value.

6.2 Recommendation

This system has successfully demonstrated temperature control system but not successfully in security system. Future recommendation on this project is included as below:

- Bead of epoxy must be used to cover up the wires and leads which connected to the sensor LM35. This is to ensure that the leads and wires are all at the same temperature as the surface, and that the LM35 temperature detection will not be affected by the air temperature. This can reduce the uncertainty of the value detected by temperature sensor and also improve it in measuring the temperature accurately.

- Use more temperature sensor to monitor temperature in different location. For this project, only one temperature sensor is used and it will detect the temperature at one location only. Besides that, if one of the sensor is not function, there we still have other sensor so that the system still functioning continuously.

- Use the high range detection and high sensitivity temperature sensor to monitor the temperature effectively in spacious room. The LM35 temperature sensor is high sensitivity but the range detection is small.

- Use 7 segment displays and VB software as back up and additional application. 7 segment displays can be used as back up system if the LCD fail to function as the temperature and password value still can be displayed. The VB software also can be used to display the value of temperature and password by interface it to the hardware during circuit operation.

6.3 Costing and Commercialization

This project consists of one main board circuits. The overall cost of the whole project is approximately RM300 and this is an affordable price for consumer to use temperature control system in their daily life as this application is able to control the temperature in server room automatically. It is an efficient professional meteorological system satisfies the needs of customers in term of costs, functionality and efficiency. Therefore, this proves that why this application always has high commercialization potential in the existing market.

REFERENCE

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   http://en.wikipedia.org/

2. Environmental Monitoring
   http://www.openxtra.co.uk/articles/environmental-monitoring-essentials

3. Recommended Server Room Temperature
   http://www.openxtra.co.uk/articles/recommended-server-room-temperature

4. Cytron Technologies Sdn Bhd. *Temperature Control System Using LM35*
   http://www.cytron.com.my/PR11.asp

5. Cytron Technologies Sdn Bhd. *Door Password Security*
   http://www.cytron.com.my/PR9.asp

6. Welcome to Exploring Electrical Engineering: Temperature Sensor LM35
   http://www.facstaff.bucknell.edu/mastascu/elessonshtml/Sensors/TempLM35.html

APPENDIX D

LCD 162A Data Sheet

162A

● GENERAL SPECIFICATION

Interface with 4-bit or 8-bit MPU(directly connected M6800 serial MPU)

Display Specification

Display color-Display background color: ①STN: Yellow-Green,Blue-Gray, Black-White

②TN: Position,Negative

Polarizer mode: Positive,Negative;Reflective ,Transflective, Transmissive

Viewing angle: 6:00 OR 12:00

Display duty: 1/16 Driving bias: 1/5

Character Generator ROM (CGROM):10080 bits(208 characterX5X8 dots)&(32 character X5X11 dots)

Character Generator RAM (CGRAM): 64 X 8 bits (8 charactersX5X8 dots)

Display Data RAM (DDRAM): 80X8 bits (80 characters max)

Mechanical characteristics (Unit:mm)

Extenal dimension: 84.0X44.0X10.0 (15.0 for LED Backlight)

View area: 61.0X15.8 Character font: 5X7dots+cursor

Character size: 2.96X5.56 Dots size: 0.528X0.625

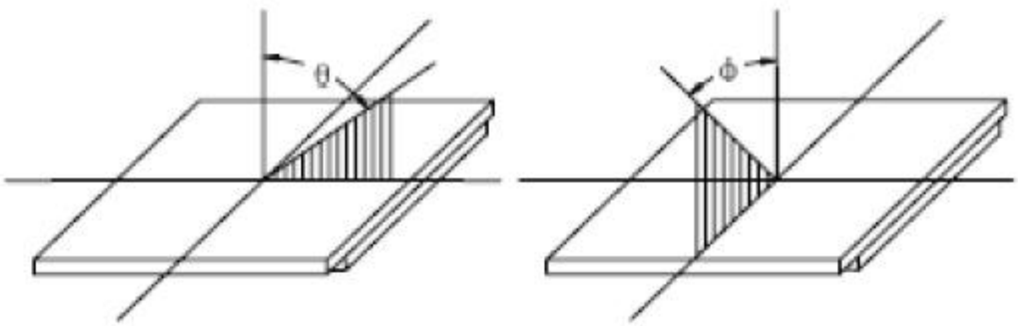
Character pitch: 3.55X6.15

POWER: +5V power

162A

● Optical Characteristics

(1) Definition of viewing Angle



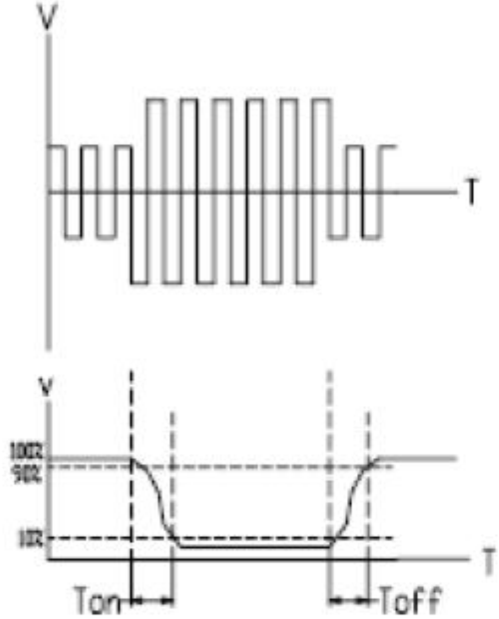
(2) Definition of Contrast Ratio:

$$\text{Contrast Ratio} = \frac{\text{Reflectance value of non-selected state brightness}}{\text{Reflectance value of selected state brightness}}$$

Test condition : standard A light source

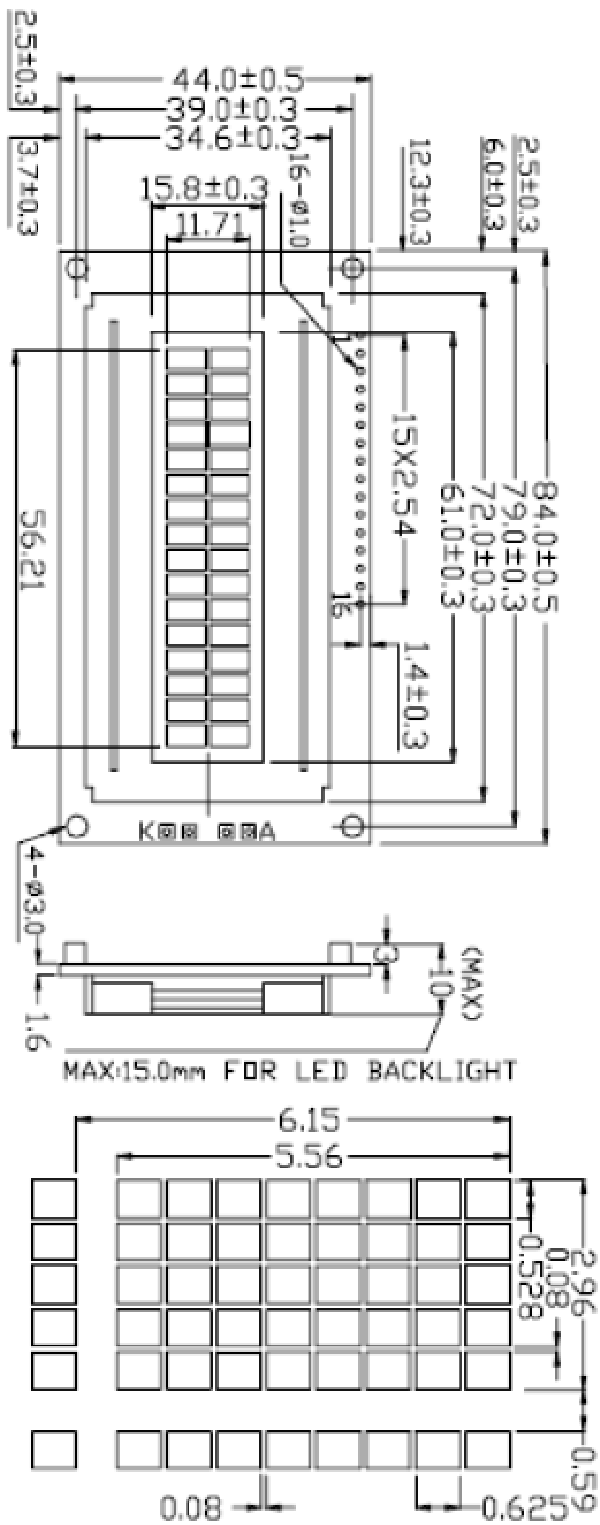
(3) Response Time

Response time is measured as the shortest period of time possible between the change in state of an LCD segment as demonstrated below



162A

- **External Dimension**



162A

● Absolute Maximum Ratings

Item	Symbol	Condition	Standard Value		Unit
			Min	Max	
Supply Voltage for logic	Vdd	Ta=25℃	-0.3	7.0	V
Supply Voltage for LCD	V5		Vdd-13.5	0	V
Input Voltage	Vi		-0.3	Vdd+0.3	V
Operating Temperature	Top	-	0	50	℃
Storage Temperature	Tstg	-	-20	70	℃

● Electrical Characteristics (Ta=25℃, Vdd= 5.0V)

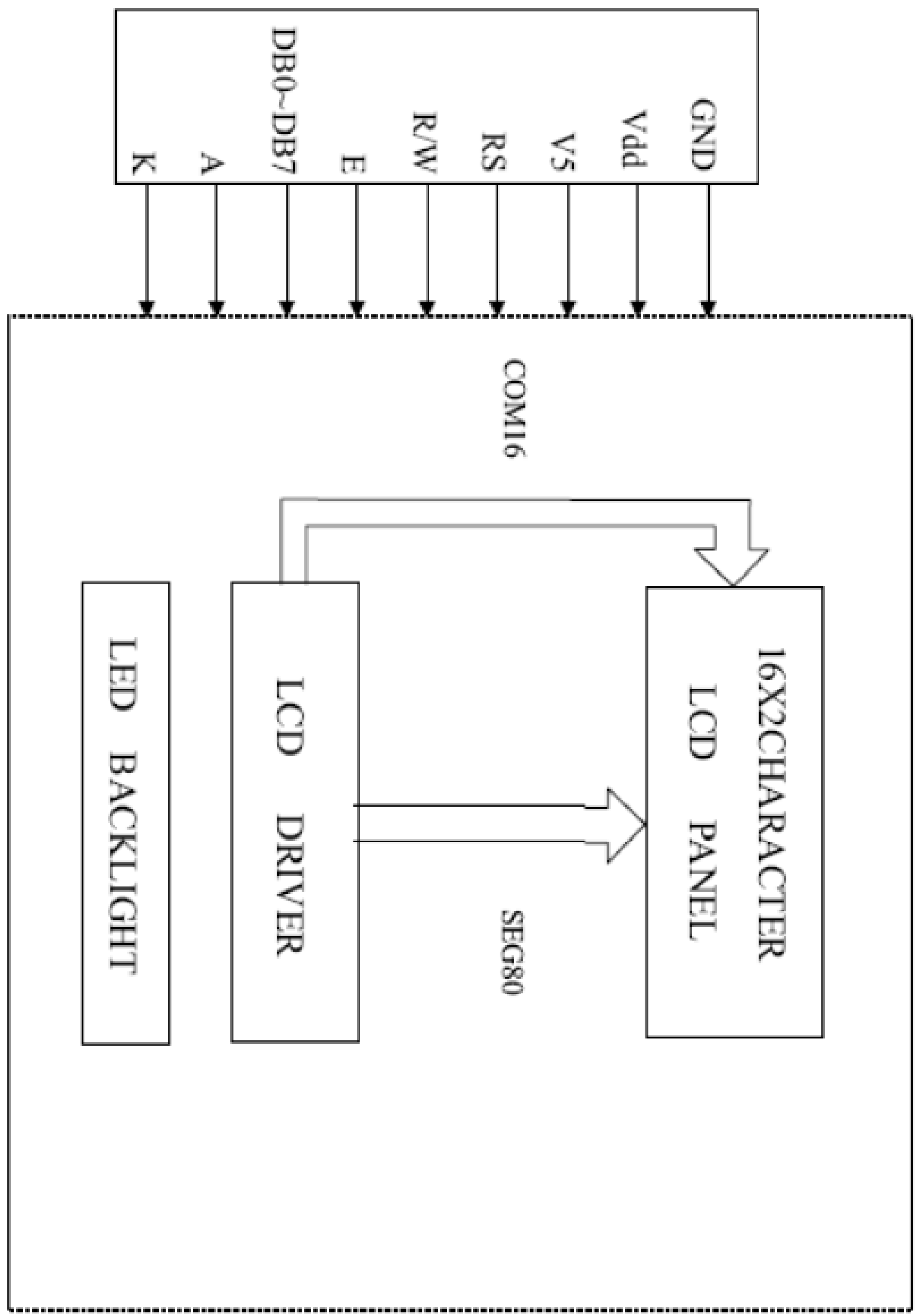
Item	Symbol	Condition	Standard Value			Unit
			Min	Type	Max	
Supply Voltage for logic	Vdd-GND	-	4.5	5.0	5.5	V
Supply Current for logic	Idd	Vdd=5V	-	1.5	3.0	mA
Driving Current for LCD	Iee		-	0.4	1.0	mA
Driving Voltage for LCD	Vdd-V5		3.8	4.5	4.9	V
Input Voltage H level	Vih		2.2	-	Vdd	V
Input Voltage L level	Vil		-0.3	-	0.6	V
Output Voltage "H"	Voh	Ioh=-0.205mA	2.4	-	-	V
Output Voltage "L"	Vol	Iol=1.2mA	-	-	0.4	V

● Absolute Maximum Ratings For LED Backlight

PARAMETER	SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
Supply Voltage	VLED	If=200mA	-	4.2	-	V
LED Forward Consumption Current	If	Vf=4.2V	-	83	-	mA
LED Allowable Dissipation	Pd	-	-	350	-	mW

162A

- **Block Diagram**



162A

● AC Characteristics (Vdd=4.5V~5.5V,Ta=-30~+85℃)

Mode	Characteristic	Symbol	Min.	Typ.	Max.	Unit
Write Mode	E Cycle Time	t_C	500	-	-	ns
	E Rise/Fall Time	t_R, t_F	-	-	20	
	E Pulse Width (High,Low)	t_W	230	-	-	
	R/W and RS Setup Time	t_{SU1}	40	-	-	
	R/W and RS Hold Time	t_{H1}	10	-	-	
	Data Setup Time	t_{SU2}	80	-	-	
	Data Hold Time	t_{H2}	10	-	-	
Read Mode	E Cycle Time	t_C	500	-	-	ns
	E Rise/Fall Time	t_R, t_F	-	-	20	
	E Pulse Width (High,Low)	t_W	230	-	-	
	R/W and RS Setup Time	t_{SU}	40	-	-	
	R/W and RS Hold Time	t_H	10	-	-	
	Data Output Delay Time	t_D	-	-	120	
	Data Hold Time	t_{DH}	5	-	-	

APPENDIX A

Temperature Sensor LM35

National Semiconductor

November 2000

LM35
Precision Centigrade Temperature Sensors

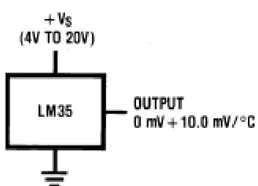
General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

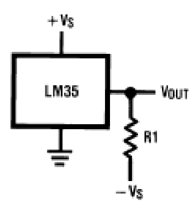
- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 μA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±¼°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications



DS005516-3

FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)



DS005516-4

Choose $R_1 = -V_S/50\ \mu A$

V_{OUT}=+1,500 mV at +150°C

= +250 mV at +25°C

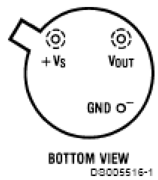
= −550 mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

 DS005516

Connection Diagrams

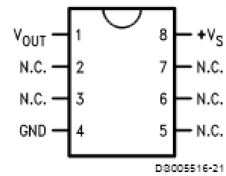
TO-46
Metal Can Package*



*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

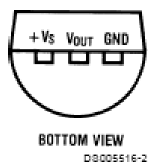
SO-8
Small Outline Molded Package



N.C. = No Connection

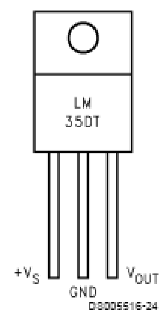
Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package



Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

TO-220
Plastic Package*



*Tab is connected to the negative pin (GND).
Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F

Absolute Maximum Ratings (Note 10)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.;	
TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-220 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	−55°C to +150°C
LM35C, LM35CA	−40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	(Max.)
Accuracy (Note 7)	T_A=+25°C	±0.2	±0.5		±0.2	±0.5		°C
	T_A=−10°C	±0.3			±0.3		±1.0	°C
	T_A=T_{MAX}	±0.4	±1.0		±0.4	±1.0		°C
	T_A=T_{MIN}	±0.4	±1.0		±0.4		±1.5	°C
Nonlinearity (Note 8)	T_{MIN}≤T_A≤T_{MAX}	**±0.18**		**±0.35**	**±0.15**		**±0.3**	°C
Sensor Gain (Average Slope)	T_{MIN}≤T_A≤T_{MAX}	**+10.0**	**+9.9, +10.1**		**+10.0**		**+9.9, +10.1**	mV/°C
Load Regulation (Note 3) 0≤I_L≤1 mA	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		mV/mA
	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.05		±0.01	±0.05		mV/V
	4V≤V_S≤30V	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	67		56	67		μA
	V_S=+5V	**105**		**131**	**91**		**114**	μA
	V_S=+30V, +25°C	56.2	68		56.2	68		μA
	V_S=+30V	**105.5**		**133**	**91.5**		**116**	μA
Change of Quiescent Current (Note 3)	4V≤V_S≤30V, +25°C	0.2	1.0		0.2	1.0		μA
	4V≤V_S≤30V	**0.5**		**2.0**	**0.5**		**2.0**	μA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.5**	**+0.39**		**+0.5**	μA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	T_J=T_{MAX}, for 1000 hours	±0.08			±0.08			°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35			LM35C, LM35D			Units
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	(Max.)
Accuracy, LM35, LM35C (Note 7)	T_A=+25˚C	±0.4	±1.0		±0.4	±1.0		˚C
	T_A=−10˚C	±0.5			±0.5		±1.5	˚C
	T_A=T_{MAX}	±0.8	±1.5		±0.8		±1.5	˚C
	T_A=T_{MIN}	±0.8		±1.5	±0.8		±2.0	˚C
Accuracy, LM35D (Note 7)	T_A=+25˚C				±0.6	±1.5		˚C
	T_A=T_{MAX}				±0.9		±2.0	˚C
	T_A=T_{MIN}				±0.9		±2.0	˚C
Nonlinearity (Note 8)	T_{MIN}≤T_A≤T_{MAX}	**±0.3**		**±0.5**	**±0.2**		**±0.5**	˚C
Sensor Gain (Average Slope)	T_{MIN}≤T_A≤T_{MAX}	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/˚C
Load Regulation (Note 3) 0≤I_L≤1 mA	T_A=+25˚C	±0.4	±2.0		±0.4	±2.0		mV/mA
	T_{MIN}≤T_A≤T_{MAX}	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation (Note 3)	T_A=+25˚C	±0.01	±0.1		±0.01	±0.1		mV/V
	4V≤V_S≤30V	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25˚C	56	80		56	80		µA
	V_S=+5V	**105**		**158**	**91**		**138**	µA
	V_S=+30V, +25˚C	56.2	82		56.2	82		µA
	V_S=+30V	**105.5**		**161**	**91.5**		**141**	µA
Change of Quiescent Current (Note 3)	4V≤V_S≤30V, +25˚C	0.2	2.0		0.2	2.0		µA
	4V≤V_S≤30V	**0.5**		**3.0**	**0.5**		**3.0**	µA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	µA/˚C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	˚C
Long Term Stability	T_J=T_{MAX}, for 1000 hours	±0.08			±0.08			˚C

Note 1: Unless otherwise noted, these specifications apply: −55˚C≤T_J≤+150˚C for the LM35 and LM35A; −40˚≤T_J≤+110˚C for the LM35C and LM35CA; and 0˚≤T_J≤+100˚C for the LM35D. V_S=+5Vdc and I_{LOAD}=50 µA, in the circuit of *Figure 2*. These specifications also apply from +2˚C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400˚C/W, junction to ambient, and 24˚C/W junction to case. Thermal resistance of the TO-92 package is 180˚C/W junction to ambient. Thermal resistance of the small outline molded package is 220˚C/W junction to ambient. Thermal resistance of the TO-220 package is 90˚C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/˚C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in ˚C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

APPENDIX B

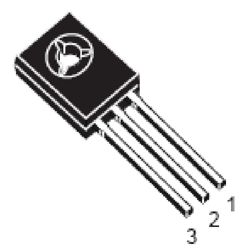
Power Transistor BD135

BD135
BD139

NPN SILICON TRANSISTORS

Type	Marking
BD135	BD135
BD135-10	BD135-10
BD135-16	BD135-16
BD139	BD139
BD139-10	BD139-10
BD139-16	BD139-16

- STMicroelectronics PREFERRED SALESTYPES



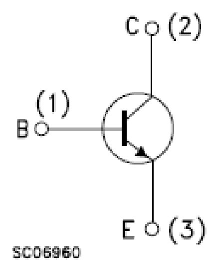
SOT-32

DESCRIPTION

The BD135 and BD139 are silicon Epitaxial Planar NPN transistors mounted in Jedec SOT-32 plastic package, designed for audio amplifiers and drivers utilizing complementary or quasi-complementary circuits.

The complementary PNP types are BD136 and BD140 respectively.

INTERNAL SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value		Unit
		BD135	BD139	
V_{CBO}	Collector-Base Voltage ($I_E = 0$)	45	80	V
V_{CEO}	Collector-Emitter Voltage ($I_B = 0$)	45	80	V
V_{EBO}	Emitter-Base Voltage ($I_C = 0$)	5		V
I_C	Collector Current	1.5		A
I_{CM}	Collector Peak Current	3		A
I_B	Base Current	0.5		A
P_{tot}	Total Dissipation at $T_c \leq 25$ °C	12.5		W
P_{tot}	Total Dissipation at $T_{amb} \leq 25$ °C	1.25		W
T_{stg}	Storage Temperature	-65 to 150		°C
T_j	Max. Operating Junction Temperature	150		°C

BD135 / BD139

THERMAL DATA

$R_{thj-case}$	Thermal Resistance Junction-case	Max	10	°C/W

ELECTRICAL CHARACTERISTICS (T_{case} = 25 °C unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
I_{CBO}	Collector Cut-off Current (I_E = 0)	V_{CB} = 30 V V_{CB} = 30 V T_C = 125 °C			0.1 10	µA µA
I_{EBO}	Emitter Cut-off Current (I_C = 0)	V_{EB} = 5 V			10	µA
$V_{CEO(sus)}$*	Collector-Emitter Sustaining Voltage (I_B = 0)	I_C = 30 mA for **BD135** for **BD139**	 45 80			 V V
$V_{CE(sat)}$*	Collector-Emitter Saturation Voltage	I_C = 0.5 A I_B = 0.05 A			0.5	V
V_{BE}*	Base-Emitter Voltage	I_C = 0.5 A V_{CE} = 2 V			1	V
h_{FE}*	DC Current Gain	I_C = 5 mA V_{CE} = 2 V I_C = 150 mA V_{CE} = 2 V I_C = 0.5 A V_{CE} = 2 V	25 40 25		 250 	
h_{FE}	h_{FE} Groups	I_C = 150 mA V_{CE} = 2 V for **BD135/BD139** group-10 for **BD135/BD139** group-16	 63 100		 160 250	

* Pulsed: Pulse duration = 300 µs, duty cycle 1.5 %

APPENDIX C

PIC Microcontroller

MICROCHIP **PIC18F2455/2550/4455/4550**

28/40/44-Pin High-Performance, Enhanced Flash USB Microcontrollers with nanoWatt Technology

Universal Serial Bus Features:

- USB V2.0 Compliant
- Low Speed (1.5 Mb/s) and Full Speed (12 Mb/s)
- Supports Control, Interrupt, Isochronous and Bulk Transfers
- Supports up to 32 endpoints (16 bidirectional)
- 1-Kbyte dual access RAM for USB
- On-chip USB transceiver with on-chip voltage regulator
- Interface for off-chip USB transceiver
- Streaming Parallel Port (SPP) for USB streaming transfers (40/44-pin devices only)

Power-Managed Modes:

- Run: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 5.8 µA typical
- Sleep mode currents down to 0.1 µA typical
- Timer1 oscillator: 1.1 µA typical, 32 kHz, 2V
- Watchdog Timer: 2.1 µA typical
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:

- Four Crystal modes including High Precision PLL for USB
- Two External Clock modes, up to 48 MHz
- Internal oscillator block:
  - 8 user-selectable frequencies, from 31 kHz to 8 MHz
  - User-tunable to compensate for frequency drift
- Secondary oscillator using Timer1 @ 32 kHz
- Dual oscillator options allow microcontroller and USB module to run at different clock speeds
- Fail-Safe Clock Monitor
  - Allows for safe shutdown if any clock stops

Peripheral Highlights:

- High-current sink/source 25 mA/25 mA
- Three external interrupts
- Four Timer modules (Timer0 to Timer3)
- Up to 2 Capture/Compare/PWM (CCP) modules:
  - Capture is 16-bit, max. resolution 6.25 ns (TCY/16)
  - Compare is 16-bit, max. resolution 100 ns (TCY)
  - PWM output: PWM resolution is 1 to 10-bit
- Enhanced Capture/Compare/PWM (ECCP) module:
  - Multiple output modes
  - Selectable polarity
  - Programmable dead time
  - Auto-Shutdown and Auto-Restart
- Enhanced USART module:
  - LIN bus support
- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI™ (all 4 modes) and I^{2}C™ Master and Slave modes
- 10-bit, up to 13-channels Analog-to-Digital Converter module (A/D) with programmable acquisition time
- Dual analog comparators with input multiplexing

Special Microcontroller Features:

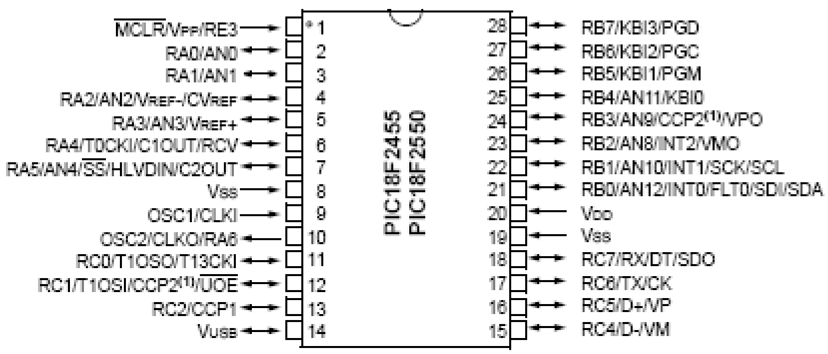
- C compiler optimized architecture with optional extended instruction set
- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Flash/Data EEPROM Retention: > 40 years
- Self-programmable under software control
- Priority levels for interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Programmable Code Protection
- Single-Supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Optional dedicated ICD/ICSP port (44-pin devices only)
- Wide operating voltage range (2.0V to 5.5V)

Device	Program Memory		Data Memory		I/O	10-bit A/D (ch)	CCP/ECCP (PWM)	SPP	MSSP		EAUSART	Comparators	Timers 8/16-bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI™	Master I^{2}C™			
PIC18F2455	24K	12288	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F2550	32K	16384	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F4455	24K	12288	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3
PIC18F4550	32K	16384	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3

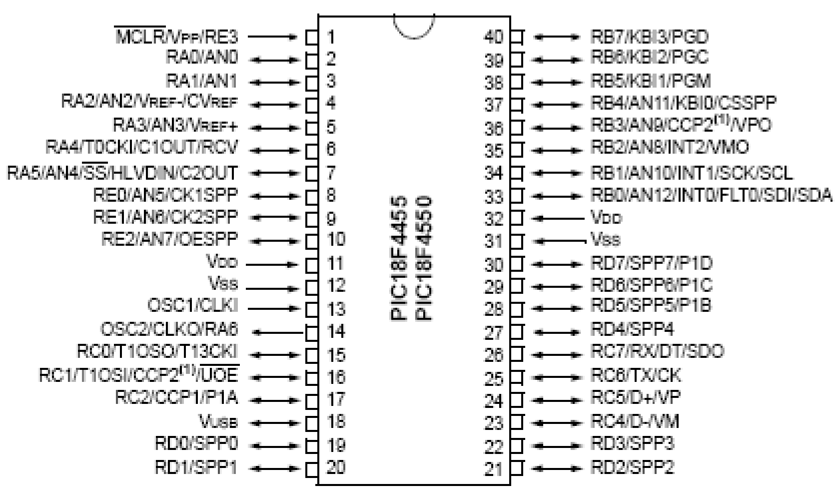
PIC18F2455/2550/4455/4550

Pin Diagrams

28-Pin PDIP, SOIC



40-Pin PDIP



Note 1: RB3 is the alternate pin for CCP2 multiplexing.

TABLE 1-3: PIC18F4455/4550 PINOUT I/O DESCRIPTIONS

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
$\overline{\text{MCLR}}$/VPP/RE3	1	18	18			Master Clear (input) or programming voltage (input).
$\overline{\text{MCLR}}$				I	ST	Master Clear (Reset) input. This pin is an active-low Reset to the device.
VPP				P		Programming voltage input.
RE3				I	ST	Digital input.
OSC1/CLKI	13	32	30			Oscillator crystal or external clock input.
OSC1				I	Analog	Oscillator crystal input or external clock source input.
CLKI				I	Analog	External clock source input. Always associated with pin function OSC1. (See OSC2/CLKO pins.)
OSC2/CLKO/RA6	14	33	31			Oscillator crystal or clock output.
OSC2				O	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO				O	—	In RC mode, OSC2 pin outputs CLKO which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
RA6				I/O	TTL	General purpose I/O pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX configuration bit is set.

3: These pins are No Connect unless the $\overline{\text{ICPRT}}$ configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the $\overline{\text{DEBUG}}$ configuration bit is cleared.

TABLE 1-3: PIC18F4455/4550 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTA is a bidirectional I/O port.
RA0/AN0	2	19	19			
RA0				I/O	TTL	Digital I/O.
AN0				I	Analog	Analog input 0.
RA1/AN1	3	20	20			
RA1				I/O	TTL	Digital I/O.
AN1				I	Analog	Analog input 1.
RA2/AN2/VREF-/CVREF	4	21	21			
RA2				I/O	TTL	Digital I/O.
AN2				I	Analog	Analog input 2.
VREF-				I	Analog	A/D reference voltage (low) input.
CVREF				O	Analog	Analog comparator reference output.
RA3/AN3/VREF+	5	22	22			
RA3				I/O	TTL	Digital I/O.
AN3				I	Analog	Analog input 3.
VREF+				I	Analog	A/D reference voltage (high) input.
RA4/T0CKI/C1OUT/RCV	6	23	23			
RA4				I/O	ST	Digital I/O.
T0CKI				I	ST	Timer0 external clock input.
C1OUT				O	—	Comparator 1 output.
RCV				I	TTL	External USB transceiver RCV input.
RA5/AN4/$\overline{SS}$/HLVDIN/C2OUT	7	24	24			
RA5				I/O	TTL	Digital I/O.
AN4				I	Analog	Analog input 4.
$\overline{SS}$				I	TTL	SPI™ slave select input.
HLVDIN				I	Analog	High/Low-Voltage Detect input.
C2OUT				O	—	Comparator 2 output.
RA6	—	—	—	—	—	See the OSC2/CLKO/RA6 pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX configuration bit is set.

3: These pins are No Connect unless the ICPRT configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the $\overline{DEBUG}$ configuration bit is cleared.

TABLE 1-3: PIC18F4455/4550 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.
RB0/AN12/INT0/FLT0/SDI/SDA	33	9	8			
RB0				I/O	TTL	Digital I/O.
AN12				I	Analog	Analog input 12.
INT0				I	ST	External interrupt 0.
FLT0				I	ST	Enhanced PWM Fault input (ECCP1 module).
SDI				I	ST	SPI™ data in.
SDA				I/O	ST	I²C™ data I/O.
RB1/AN10/INT1/SCK/SCL	34	10	9			
RB1				I/O	TTL	Digital I/O.
AN10				I	Analog	Analog input 10.
INT1				I	ST	External interrupt 1.
SCK				I/O	ST	Synchronous serial clock input/output for SPI mode.
SCL				I/O	ST	Synchronous serial clock input/output for I²C mode.
RB2/AN8/INT2/VMO	35	11	10			
RB2				I/O	TTL	Digital I/O.
AN8				I	Analog	Analog input 8.
INT2				I	ST	External interrupt 2.
VMO				O	—	External USB transceiver VMO output.
RB3/AN9/CCP2/VPO	36	12	11			
RB3				I/O	TTL	Digital I/O.
AN9				I	Analog	Analog input 9.
CCP2(1)				I/O	ST	Capture 2 input/Compare 2 output/PWM 2 output.
VPO				O	—	External USB transceiver VPO output.
RB4/AN11/KBI0/CSSPP	37	14	14			
RB4				I/O	TTL	Digital I/O.
AN11				I	Analog	Analog input 11.
KBI0				I	TTL	Interrupt-on-change pin.
CSSPP				O	—	SPP chip select control output.
RB5/KBI1/PGM	38	15	15			
RB5				I/O	TTL	Digital I/O.
KBI1				I	TTL	Interrupt-on-change pin.
PGM				I/O	ST	Low-Voltage ICSP™ Programming enable pin.
RB6/KBI2/PGC	39	16	16			
RB6				I/O	TTL	Digital I/O.
KBI2				I	TTL	Interrupt-on-change pin.
PGC				I/O	ST	In-Circuit Debugger and ICSP programming clock pin.
RB7/KBI3/PGD	40	17	17			
RB7				I/O	TTL	Digital I/O.
KBI3				I	TTL	Interrupt-on-change pin.
PGD				I/O	ST	In-Circuit Debugger and ICSP programming data pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX configuration bit is set.

3: These pins are No Connect unless the ICPRT configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the DEBUG configuration bit is cleared.

TABLE 1-3: PIC18F4455/4550 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTC is a bidirectional I/O port.
RC0/T1OSO/T13CKI	15	34	32			
RC0				I/O	ST	Digital I/O.
T1OSO				O	—	Timer1 oscillator output.
T13CKI				I	ST	Timer1/Timer3 external clock input.
RC1/T1OSI/CCP2/ $\overline{UOE}$	16	35	35			
RC1				I/O	ST	Digital I/O.
T1OSI				I	CMOS	Timer1 oscillator input.
CCP2(2)				I/O	ST	Capture 2 input/Compare 2 output/PWM 2 output.
$\overline{UOE}$				O	—	External USB transceiver $\overline{OE}$ output.
RC2/CCP1/P1A	17	36	36			
RC2				I/O	ST	Digital I/O.
CCP1				I/O	ST	Capture 1 input/Compare 1 output/PWM 1 output.
P1A				O	TTL	Enhanced CCP1 PWM output, channel A.
RC4/D-/VM	23	42	42			
RC4				I	TTL	Digital input.
D-				I/O	—	USB differential minus line (input/output).
VM				I	TTL	External USB transceiver VM input.
RC5/D+/VP	24	43	43			
RC5				I	TTL	Digital input.
D+				I/O	—	USB differential plus line (input/output).
VP				I	TTL	External USB transceiver VP input.
RC6/TX/CK	25	44	44			
RC6				I/O	ST	Digital I/O.
TX				O	—	EUSART asynchronous transmit.
CK				I/O	ST	EUSART synchronous clock (see RX/DT).
RC7/RX/DT/SDO	26	1	1			
RC7				I/O	ST	Digital I/O.
RX				I	ST	EUSART asynchronous receive.
DT				I/O	ST	EUSART synchronous data (see TX/CK).
SDO				O	—	SPI™ data out.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX configuration bit is set.

3: These pins are No Connect unless the $\overline{ICPRT}$ configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the $\overline{DEBUG}$ configuration bit is cleared.

PIC18F2455/2550/4455/4550

TABLE 1-3: PIC18F4455/4550 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number PDIP	QFN	TQFP	Pin Type	Buffer Type	Description
						PORTD is a bidirectional I/O port or a Streaming Parallel Port (SPP). These pins have TTL input buffers when the SPP module is enabled.
RD0/SPP0	19	38	38			
RD0				I/O	ST	Digital I/O.
SPP0				I/O	TTL	Streaming Parallel Port data.
RD1/SPP1	20	39	39			
RD1				I/O	ST	Digital I/O.
SPP1				I/O	TTL	Streaming Parallel Port data.
RD2/SPP2	21	40	40			
RD2				I/O	ST	Digital I/O.
SPP2				I/O	TTL	Streaming Parallel Port data.
RD3/SPP3	22	41	41			
RD3				I/O	ST	Digital I/O.
SPP3				I/O	TTL	Streaming Parallel Port data.
RD4/SPP4	27	2	2			
RD4				I/O	ST	Digital I/O.
SPP4				I/O	TTL	Streaming Parallel Port data.
RD5/SPP5/P1B	28	3	3			
RD5				I/O	ST	Digital I/O.
SPP5				I/O	TTL	Streaming Parallel Port data.
P1B				O	—	Enhanced CCP1 PWM output, channel B.
RD6/SPP6/P1C	29	4	4			
RD6				I/O	ST	Digital I/O.
SPP6				I/O	TTL	Streaming Parallel Port data.
P1C				O	—	Enhanced CCP1 PWM output, channel C.
RD7/SPP7/P1D	30	5	5			
RD7				I/O	ST	Digital I/O.
SPP7				I/O	TTL	Streaming Parallel Port data.
P1D				O	—	Enhanced CCP1 PWM output, channel D.

Legend: TTL = TTL compatible input; ST = Schmitt Trigger input with CMOS levels; O = Output; CMOS = CMOS compatible input or output; I = Input; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX configuration bit is set.

3: These pins are No Connect unless the ICPRT configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the $\overline{DEBUG}$ configuration bit is cleared.

TABLE 1-3: PIC18F4455/4550 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTE is a bidirectional I/O port.
RE0/AN5/CK1SPP	8	25	25			
RE0				I/O	ST	Digital I/O.
AN5				I	Analog	Analog input 5.
CK1SPP				O	—	SPP clock 1 output.
RE1/AN6/CK2SPP	9	26	26			
RE1				I/O	ST	Digital I/O.
AN6				I	Analog	Analog input 6.
CK2SPP				O	—	SPP clock 2 output.
RE2/AN7/OESPP	10	27	27			
RE2				I/O	ST	Digital I/O.
AN7				I	Analog	Analog input 7.
OESPP				O	—	SPP output enable output.
RE3	—	—	—	—	—	See $\overline{MCLR}$/VPP/RE3 pin.
VSS	12, 31	6, 30, 31	6, 29	P	—	Ground reference for logic and I/O pins.
VDD	11, 32	7, 8, 28, 29	7, 28	P	—	Positive supply for logic and I/O pins.
VUSB	18	37	37	O	—	Internal USB 3.3V voltage regulator output.
NC/ICCK/ICPGC	—	—	12			No Connect or dedicated ICD/ICSP™ port clock.(3)
ICCK				I/O	ST	In-Circuit Debugger clock.
ICPGC				I/O	ST	ICSP programming clock.
NC/ICDT/ICPGD	—	—	13			No Connect or dedicated ICD/ICSP port clock.(3)
ICDT				I/O	ST	In-Circuit Debugger data.
ICPGD				I/O	ST	ICSP programming data.
NC/$\overline{ICRST}$/ICVPP	—	—	33			No Connect or dedicated ICD/ICSP port Reset.(3)
$\overline{ICRST}$				I	—	Master Clear (Reset) input.
ICVPP				P	—	Programming voltage input.
NC/ICPORTS	—	—	34	P	—	No Connect or 28-pin device emulation.(3)
ICPORTS						Enable 28-pin device emulation when connected to VSS.
NC	—	13	—	—	—	No Connect.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX configuration bit is set.

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```
DEFINE OSC 20 ' Use Oscillator 20 MHz
DEFINE LCD_DREG PORTB' Set LCD Data port
DEFINE LCD_DBIT 4 ' Set starting Data bit (0 or 4) if 4-bit bus
DEFINE LCD_RSREG PORTD ' Set LCD Register Select port
DEFINE LCD_RSBIT 2 ' Set LCD Register Select bit
DEFINE LCD_EREG PORTD ' Set LCD Enable port
DEFINE LCD_EBIT 3 ' Set LCD Enable bit
DEFINE LCD_BITS 4 ' Set LCD bus size (4 or 8 bits)
DEFINE LCD_LINES 2 ' Set number of lines on LCD
DEFINE LCD_COMMANDUS 2000 ' Set command delay time in us
DEFINE LCD_DATAUS 50 ' Set data delay time in us

'trisb = %00000000
'trisd = %00000000

DEFINE ADC_BITS  8      'Set number of bits in result (8, 10 or 12)
DEFINE ADC_CLOCK 3      'Set clock source (rc =3)
DEFINE ADC_SAMPLEUS 50  'Set sampling time in microseconds

TRISA.0 = 1     'SET AS INPUT PORTA.0
TRISD.4 = 0     'SET AS OUTPUT PORTD.4
TRISD.5 = 0     'SET AS OUTPUT PORTD.5
TRISD.6 = 0     'SET AS OUTPUT PORTD.6
TRISD.7 = 0     'SET AS OUTPUT PORTD.7


TEMP VAR BYTE
Y VAR BYTE

ADCON0 =%00000001
ADCON1 =%00000000
```

```
pause 100

MAIN:

adcin 0, TEMP

Y = 100 - 2*TEMP

LCDout $fe, 1
LCDout $fe, 2

LCDOUT $FE, $80
lcdout "TEMPERATURE"
LCDOUT $FE, $C0
lcdout dec y,"CELCIUS"
pause 100


IF TEMP > 30 THEN GOTO LED3
   LOW  PORTD.4
   low  PORTD.5
   high PORTD.6
   LOW  PORTD.7
   GOTO LOOP

LED1:
if temp > 25 then goto LED2
   HIGH PORTD.4
   LOW  PORTD.5
   LOW  PORTD.6
```

```
    LOW  PORTD.7
    GOTO LOOP

LED2:
    LOW  PORTD.4
    HIGH PORTD.5
    LOW  PORTD.6
    LOW  PORTD.7
    GOTO LOOP



LED3 :
if TEMP > 35 THEN GOTO LED1
    LOW  PORTD.4
    LOW  PORTD.5
    HIGH PORTD.6
    HIGH PORTD.7
    GOTO LOOP

LOOP:
PAUSE 100
GOTO MAIN

END
```