DEVELOPMENT OF FUZZY CONTROLLER TO CONTROL VEHICLE TEMPERATURE

DEVANDRAN A/L KRISNAN

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ABSTRACT

Car is the most convenient transportation for each individual compare to public transport. The car which parked at open parking will face problem with increasing temperature inside the car up to 50 degree Celsius. This will make the driver and passenger become uncomfortable while entering the car. Of less significance is damage to temperature sensitive material such as player, GPS system, laptop and LCD screen and plastic components of the car. So the need of temperature controller is really necessary so that the hot air inside the car will be remove and at the same time will reduce the temperature inside the car. This project related to car cooling system and more particularly to a system for cooling passenger compartment of the car without operates the car engine. In this project, a practical application of a closed loop system using fuzzy controller in the vehicle was carried out and control using a Peripheral Integral Controller 16F873A. The temperature data is acquired from SN-LM35DZ temperature sensor and control speed fan to vents hot air out from vehicle powered by solar system in the car. The model has been developed to analysis the system and to get the result of effectiveness of this project.

ABSTRAK

Kereta adalah pengangkutan yang paling mudah bagi setiap individu berbanding dengan pengangkutan awam. Kereta yang diletakkan di tempat letak kereta terbuka akan menghadapi masalah dengan meningkatkan suhu dalam kereta sehingga ke 50 darjah Celcius. Ini menyebabkan pemandu dan penumpang tidak selesa ketika memasuki kereta. Kerosakan daripada suhu yang tinggi pada barang sensitive seperti pemain cakera padat, GPS, LCD, laptop dan komponen plastik kereta.Oleh itu, keperluan kawalan suhu adalah penting supaya udara panas dalam kereta dapat mengeluarkan dan pada masa yang sama akan mengurangkan suhu dalam kereta. Kerosakan daripada suhu yang tinggi pada barang sensitive seperti pemain cakera padat, GPS, LCD, laptop dan komponen plastik kereta. Dalam projek ini, praktikal sistem kawalan tutup kawalan logik digunakan dalam kenderaan dengan mikrochip PIC16F873A. Suhu data didapati dengan menggunakan sensor SN-LM35DZ dan hasil untuk mengeluarkan udara panas dari kereta menggunakan kipas. Projek ini menggunakan solar sebagai sumbere tenaga untuk menjalankan sistem kipas penyejuk. Model projek ini menggunakan solar panel telah diaplikasikan untuk mendapatkan keputusan dan keberkesanan projek ini.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	EXPLANATION
TCFL	Temperature Control Using Fuzzy Logic Techniques
SISO	single input single output
PCB	Printed Circuit Board
I/O	Input/output
LED	Light emitter diode

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Air conditioning systems are essential in most of our daily lives. Our expectations of such systems have been raised to demand more than just temperature control, and it is increasingly desirable to apply these systems in varying situations and environments. As sunlight hits the windshield, enters the car, and heats up the interior, the air inside warms up, and the windows warm up. The windows, because they are now hotter than the air outside, transfer heat back to the air around the car (heat moves from hotter bodies to colder ones, and the bigger the difference, the faster the heat moves). So the 'steady state' is reached when the amount of heat going into the car equals the amount of heat going out of the car [2] .

The hotter the inside temperature, the more heat will be transferred to the surroundings. Thus, when the car is cool, the sun will heat it up more quickly, but eventually it will heat up so much that the heat gained from the sun is matched by the heat lost to the air. Other factors that matter are the presence of wind (just like wind cools you faster, it will cool your car faster too).

Figure 1.1: Model of a car using cooling fan to remove hot air out

Figure 1.1 shows model of a car that using cooling fan to control interior vehicle temperature when car is in parked condition under the sunlight. With regards to both driver and passenger comfort and safety, a lot of factors must be taken in account. A comfortable and safe environment is often difficult to define and affected by sometimes contradictory factors. Fuzzy logic control provides an effective and economic approach to this problem. Fuzzy controllers incorporated in the latest model automobiles designed by Japanese auto makers provide proof that temperature control in diverse environments can be solved. The key to a good solution lies in thorough analysis of factors affecting the control target and the kinds of sensors and sensing techniques used to detect these factors [1]. Fuzzy logic does not necessitate a mathematical model of the system and yet capable to provide non-linear relationship induced by membership functions, rules and defuzzification. These features make fuzzy logic promising for process control where conventional control technologies do a poor job and human operator experience exists. By these reasons, fuzzy controller is used to control air conditioners in a climate control system.

Knowledge base of the fuzzy carries out rule inference based either on human experience or an operator control actions in the form of if-then rule structure. On the other hand, the inference will do the decision-making action based on the obtained input conditions and rule in the knowledge base. The resulting is actually a non-linear relationship rather than a logic relationship.

Fuzzy logic does not necessitate a mathematical model of the system and yet capable to provide non-linear relationship induced by membership functions, rules and defuzzification. These features make fuzzy logic promising for process control where conventional control technologies do a poor job and human operator experience exists. By these reasons, fuzzy controller is used to control air conditioners in a climate control system. Solar system is a system used the sun to power a cooling fan to vent hot air out of your car when parked. This solar system utilize maximum as power source rechargeable battery to run cooling fan.

Figure 1.2: Solar powered to run the cooling fan

1.2 PROBLEM STATEMENT

Temperature inside the vehicle is very important to provide comfort to the car passenger. The temperature can be controlled by using air conditioning system that operate when the car engine in operation. However, when the car is left or park directly under the sunlight, the temperature inside vehicle is increased because of the heat air flow inside it.

1.3 OBJECTIVES

The objective of the project is as follow;

(I) To design fuzzy system to control vehicle temperature.

(II) To develop a model when car is park powered by stand alone solar energy.

(III) To analysis the effectiveness of fuzzy controller system.

1.4 SCOPES

These are the scopes that will be covered in this project:

(I) To create a heat removal using cooling fan and maintain the temperature in a vehicle implement by microchip type 16F873A-I/SP.

(II) To develop fuzzy controller system to control temperature in more intelligently in 5 different membership in according to the rules. Solar panel 20W Flexi PV panel (12V) V as power supply for rechargeable battery so it runs the cooling fan.

(III) Analysis of data from condition that manipulated.

1.5 SUMMARY OF CHAPTER

Fuzzy logic is an artificial intelligence system which applies meaning to imprecise concepts. Rather than simply labeling a statement either “true” or “false” as traditional binary logic does, a statement is instead mapped along a continuum of values.

Fuzzy logic is often used for function approximation and for systems of control. In industry, it has been used to create “smart” appliances to transition smoothly between states. For example, early engineering projects using fuzzy logic include subway systems in Tokyo and Sendai, Japan that use fuzzy logic to accelerate and brake imperceptibly to the passengers. [2] Fuzzy logic is also used in a variety of different controllers and software, including chips that control the auto-focus of cameras, artificial intelligence for enemies in video games, edge detection, pattern recognition algorithm, data mining and rules for language filters.

Humans think in terms or relative ranges; our linguistic statements about the world include adverbs, adjectives, intensifiers and other modifiers. These modifiers are situated contextually and change depending on knowledge of the contexts. Fuzzy logic captures this context by allowing linguistic statements to hold a range of values, a continuum rather than a singularity, hence the term “fuzzy”.

CHAPTER 2

LITERATURE REVIEW

2.1 Fuzzy Logic Control

The concept of Fuzzy Logic (FL) was conceived by Lotfi Zadeh, a professor at the University of California at Berkley, and presented not as a control methodology, but as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership [4]. This approach to set theory was not applied to control systems until the 70's due to insufficient small-computer capability prior to that time. Professor Zadeh reasoned that people do not require precise, numerical information input, and yet they are capable of highly adaptive control [4]. If feedback controllers could be programmed to accept noisy, imprecise input, they would be much more effective and perhaps easier to implement. Unfortunately, U.S. manufacturers have not been so quick to embrace this technology while the Europeans and Japanese have been aggressively building real products around it. Figure 2.1 show four parts flow in the fuzzy logic controller while figure 2.2 shows the architecture of the Fuzzy logic controller.

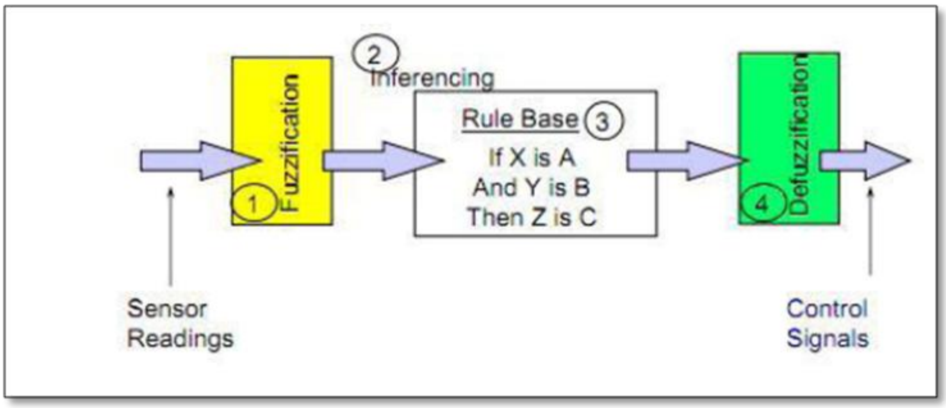

Figure 2.1: Flow of the fuzzy logic controller

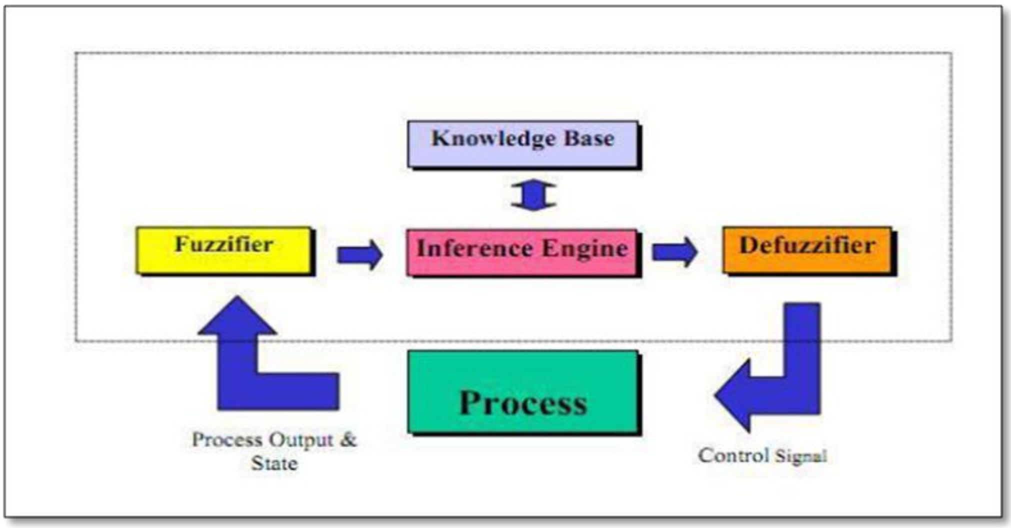

Figure 2.2 : Typical Fuzzy Controller Architecture

Most real life physical systems are actually non-linear systems [1]. Conventional design approaches use different approximation methods to handle non-linearity. Some typical choices are, linear, piecewise linear, and lookup table approximations to trade off factors of complexity, cost, and system performance. A linear approximation technique is relatively simple, however it tends to limit control performance and may be costly to implement in certain applications [5]. A piecewise linear technique works better, although it is tedious to implement because it often requires the design of several linear controllers. A lookup table technique may help improve control performance, but it is difficult to debug and tune.

Furthermore in complex systems where multiple inputs exist, a lookup table may be impractical or very costly to implement due to its large memory requirements [5].

Fuzzy logic provides an alternative solution to non-linear control because it is closer to the real world [1]. Non-linearity is handled by rules, membership functions, and the inference process which results in improved performance, simpler implementation, and reduced design costs [1].

In many applications Fuzzy Logic can result in better control performance than linear, piecewise linear, or lookup table techniques [1]. For instance, a typical problem associated with traditional techniques is trading-off the controller's response time versus overshoot. For the simple one-input temperature controller example this is illustrated in Figure 2.1:

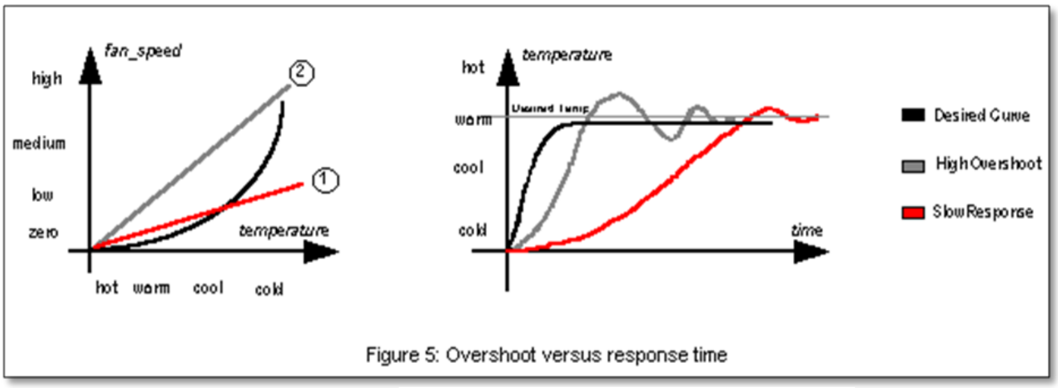

Figure 2.3: Overshoot Versus Response Time

The first linear approximation for the desired curve generates a slow output response with no overshoot, which implies that the room would be too cold for a while. The second linear approximation results in faster response with an overshoot and subsequent fluctuations, which implies that the temperature will be uncomfortable for a period of time [6] .

With fuzzy logic we can use rules and membership functions to approximate any continuous function to any degree of precision. Table2.1 illustrates how we can approximate the desired control curve for our temperature controller using four points (or four rules). We can also add more rules to increase the accuracy of the approximation (similar to a Fourier transform), which yields an improved control performance. Rules are much simpler to implement and much easier to debug and tune than piecewise linear or lookup table techniques.

IF temperature IS cold **THEN** force IS high
IF temperature IS cool **THEN** force IS medium
IF temperature IS warm **THEN** force IS low
IF temperature IS hot **THEN** force IS zero

Table 2.1: Rule Base for Temperature Control

Rules are not like a lookup table because the fuzzy arithmetic interpolates the shape of the non-linear function [4]. The combined memory required for the labels and fuzzy inference is substantially less than a lookup table, especially for multiple input systems [4]. As a result, processing speed can be improved as well.

Another example of robust control that can be achieved with fuzzy logic is the classical problem of the inverted pendulum. A conventional controller for the pendulum depends on system parameters such as length, weight, and mass. If the parameters change, then we need to re-design our controller. With fuzzy control this is not necessary because a fuzzy system is robust [5]. Aptronix has demonstrated an actual device where we can vary the weight or length of the pendulum and the system is still stable using the original set of rules.

By using a more natural rule-based approach which is closer to the real world, Fuzzy control can offer a superior performance and a better trade-off between system robustness and sensitivity, which results into handling non-linear control better than traditional methods [4].

An on-off controller is the simplest form of temperature control device. The output from the device is either on or off, with no middle state. An on-off controller will switch the output only when the temperature crosses the set point. For heating control, the output is on when the temperature is below the set point, and off above set point. Since the temperature crosses the set point to change the output state, the process temperature will be cycling continually, going from below set point to above, and back below.

In cases where this cycling occurs rapidly, and to prevent damage to contactors and valves, an on/off differential, or "hysteresis," is added to the controller operations. This differential requires that the temperature exceed set point by a certain amount before the output will turn off or on again. On-off differential prevents the output from "chattering" (that is, engaging in fast, continual switching if the temperature's cycling above and below the set point occurs very rapidly). On-off control is usually used where a precise control is not necessary, in systems which cannot handle the energy's being turned on and off frequently, where the mass of the system is so great that temperatures change extremely slowly, or for a temperature alarm. One special type of on-off control used for alarm is a limit controller [4] . This controller uses a latching relay, which must be manually reset, and is used to shut down a process when a certain temperature is reached.

Nowadays, Fuzzy logic has been applied at most electronic home appliance such as rice cooker and washing machine. Same goes to the industry. They are using this method to control their machines. Fuzzy logic control constitutes one of the fastest growing areas of control technology development, and has better prospects for the future.

Fuzzy logic is more effective in feedback control system and easier to implement. Fuzzy control system divide into the single variable fuzzy control system and the multi- variables fuzzy control system.

2.2 Car Temperature

By definition, car temperature is the process by which 'clean' air (normally outdoor air) is intentionally provided to a space and stale air is removed. An automobile air conditioning system for controlling the inside temperature of an automobile to maintain the inside temperature in a comfortable range or to protect the content of the automobile from becoming over-heated on excessively hot days when the automobile is parked or not in use. It is a common practice in warmer climates to leave a small opening at the top of the windows to permit some circulation of air and the escape of heated air from an automobile parked in a hot location. This practice is of little value and introduces some security risk as it is possible to open most automobile doors with a wire if access can be gained through a window [7] .

Sometimes temperature in a cabin of a vehicle raises, during its parking time with the engine stopped, to an extremely high degree which can never experience in our daily life. For instance, if a vehicle is left under the burning sun, temperature in a cabin of the vehicle goes up to 60 to 70 degree Celsius. Meanwhile 30°C would be the room temperature. Main apparatus use in this project is thermocouple monitor, CPU fans, and J-Type thermocouple. Eight point of thermocouple is set inside the car cabin which is reacted as the temperature sensor. The result of the experiment shows that temperature inside car cabin can quickly rise to a level that is not suitable for people to enter the car. The highest temperature taken in the experiment of fully closed cabin is 70.2°C and the minimum temperature taken is 29.7°C. For the second experiment of fully closed cabin, maximum temperature is 72.7C, and the minimum temperature ia 31.1C [8] .

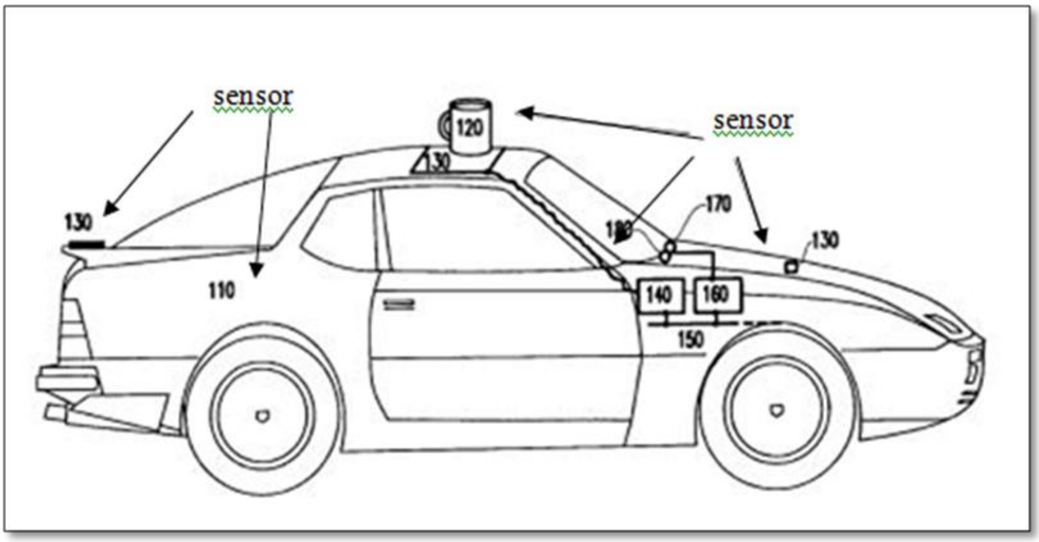

Figure 2.4: Model of a car with sensors

The car absorbs heat from the surrounding until it reaches thermal equilibrium, where the car and the surrounding temperature is balanced. However, heat conducts faster from solids then from gases, so we feel the heat much faster. Also, there is less air circulation in a car due to limited space, resulting in heat unable to escape while in surrounding, the hotter particles can float up and allow the heat to be transferred away. Figure 2.5 shows temperature variation of the front panel surface and air space

temperature near drivers head without ventilation. While this experiment was carried out, the atmospheric temperature was 32˚C during 10:00am to 3:00pm. Front panel surface had the maximum temperature of car cabin which is 83˚C while the maximum

air space temperature near driver head was found 67˚C [8] .

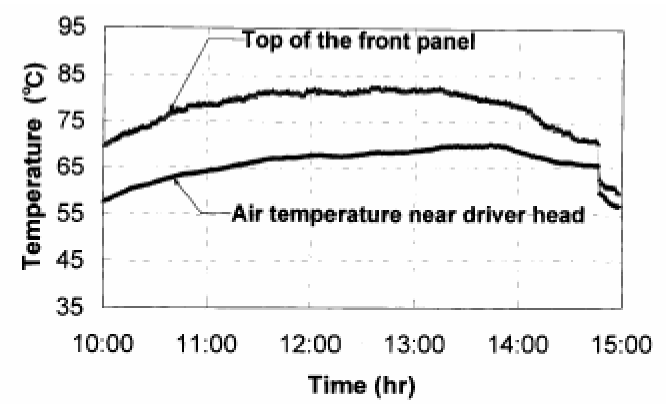

Figure 2.5 : Temperature variations with time at different locations (without cooling)

2.3 Standalone Solar Power Systems

Standalone Solar Power Systems are completely independent from any electric utility grid. They are most often used in remote areas where electricity is not available or where the connection fees of the grid are higher than the cost of an alternative energy system. Standalone solar systems (also known as autonomous, or off grid systems) are used to collect and store solar energy to be used by household appliances [9]. These systems typically generate from 100 Watts (very small systems) to 5 kilowatts (larger systems, multifamily homes). During the day, the electricity generated is used to power the home and charge the batteries. At night, and during rainy days, all necessary power is provided by the batteries.

In some cases, where it is important that power is always available, some stand alone systems, known as PV-hybrid systems or island systems, may also have another source of power such as a wind turbine, bio-fuel or a diesel generator. Power generated from a standalone system is considered DC (direct current), and is stored in a battery and converted to AC (alternate current). Standalone Solar Power Systems are the perfect choice for remote rural or villages to provide continuous reliable power. Solar modules are only one part of a standalone solar system [9] . They work together with other components: batteries, inverters, and transformers. Together with power distribution panels and metering devices they complete the process.

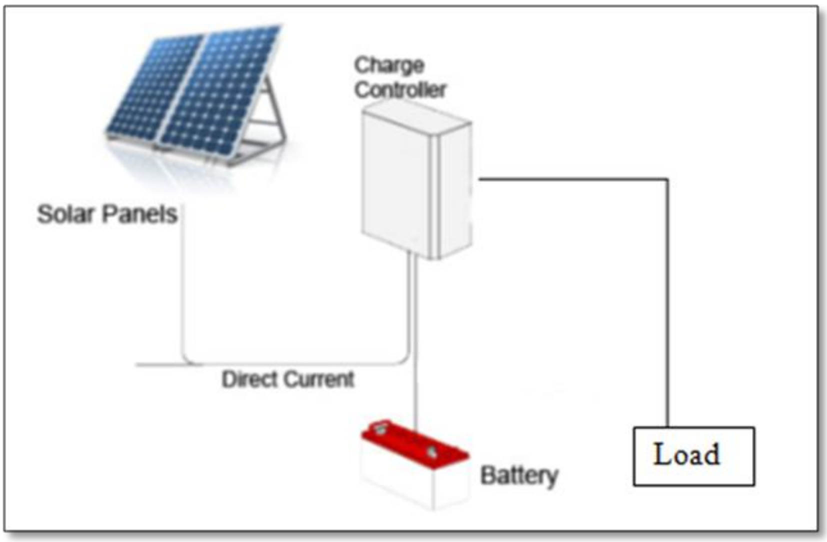

Figure 2.6: Standalone Solar System

2.3.1 Solar Panel

The DC electricity produced by the solar panel or module(s) is used to charge batteries via a solar charge controller. Any DC appliances that are connected to the battery will need to be fused. DC lights are normally connected to the charge controller. Any AC appliances are powered via an inverter connected directly to the batteries. Most standalone solar systems need to be managed properly. Users need to know the limitations of a system and tailor energy consumption according to how sunny it is and the state of charge (SOC) of the battery. The solar panels need to be configured to match the system DC voltage, which is determined by the battery. System voltages are typically, 12V DC and 24V DC, larger systems will operate at 48V DC. The operating voltage of a solar panel in a stand-alone system must be high enough to charge the batteries. For example, a 12V battery will require 14.4V to charge it [9] . The solar panel must be able to deliver this voltage to the battery after power losses and voltage drop in the cables and charge controller and in conditions in which the solar cells operate at a high temperature. A solar panel with a Voc of about 20V is required to reliably charge a 12V battery.

2.3.2 Charge Controllers

A charge controller is designed to protect the battery and ensure it has a long working life without impairing the system efficiency. Batteries should not be overcharged and the function of the charge controller is to ensure that the battery is not over charged [9] . Charge controllers are designed to function to protect the battery from over-discharge, normally referred to as low voltage disconnect (LVD) that disconnects the battery from the load when the battery reaches a certain depth of discharge (DOD). Thus, to protect the battery from over-charging by limiting the charging voltage - this is important with sealed batteries - it is usually referred to as high voltage disconnect (HVD) and prevent current flowing back into the solar panel during the night, so called reverse current.

2.3.3 Batteries

The power requirements of standalone solar systems are rarely in sync with the battery charging. Appliances and loads need to be powered when there is sufficient solar radiation, during overcast weather and during the night. Bad weather may last for several days and the daily charging and discharging of the batteries takes its toll on them. Batteries that are able to handle the constant charging and discharging are known as deep cycle batteries [9]. Batteries need to have a good charging efficiency, low charging currents and low self-discharge. The important characteristic to look for are capacity, cycle life, performance, size and space requirements, self discharge-rate and installation.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The method of this project discusses the overall architecture of the project and methodology or approaches used. Section 3.2 will discuss about the design circuit, list of component and the model of the project. The overall architecture or system block diagram of the project will be presented in Section 3.2.1. Section 3.3 explain the algorithm used in software and development. Meanwhile, in Section 3.4 explain the hardware and development includes the reason for selected components or method used including the prototype of this project. The discussion will include the problem statement definition, planning, research about project, designing, procurement, fabrication and testing the improvement or modification.

3.1.1 Procedure Identification

This is the flow process of the project is developed from the beginning to the end consist of planning and design, learning, testing and install.

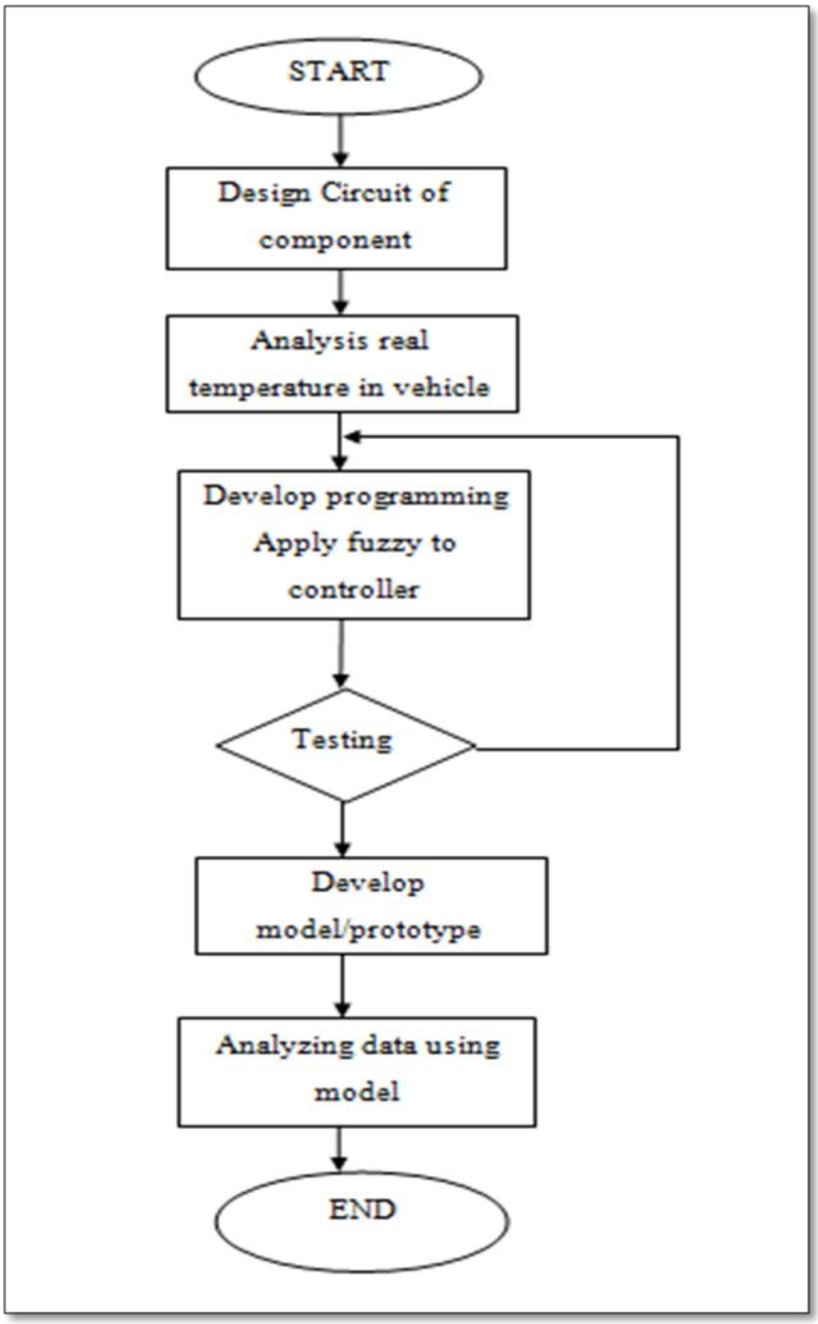

Figure 3.1 : Flow process of the project

The hardware circuit board is produced by using the common process of PCB board manufacturing. Continue the process until the process of placing components on the circuit. Solder all the components and test whether the circuit is working or not. If there is damage to the circuit, repair the circuit back. An analysis of the real car temperature inside and outside car data has been taken for 10 hours from 9 morning until 7 evening on 3rd Mac 2012 to determine the maximum and minimum temperature to set the membership function for fuzzy logic. Programme has been developing according to fuzzy logic and programming it into microchip PIC16F873A. This circuit system is tested connecting to the fan. Battery power supply 12V is applied to the circuit board. Model has been develop. Finally the circuit will be placed inside the model to get the result by measuring the temperature reading.

3.1.2 Temperature Control System

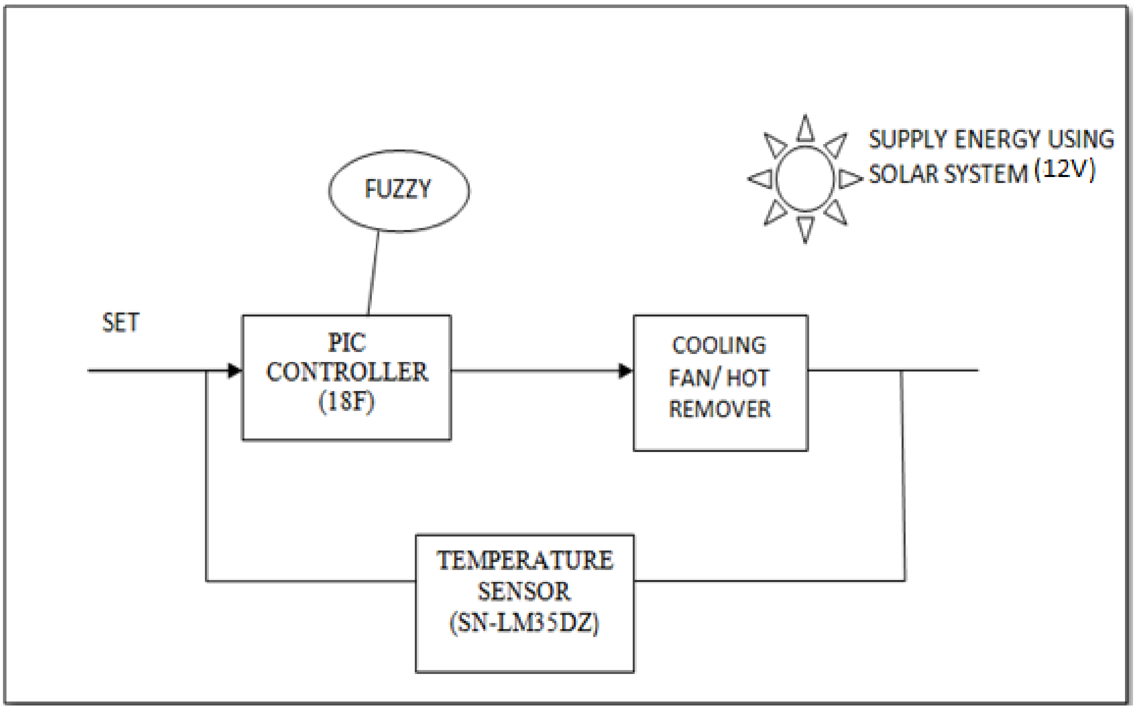

Figure 3.2: Block Diagram

3.1.3 Process sequences

This system used solar panel as a source of energy to run the cooling fan. Solar panel will provide energy to the battery. It converts heat to energy using solar charger controller. The function battery is to step down the 12VDC from solar panel to the operating voltage of 5VDC which is use by the other parts of the system. To generate the PIC 16F873A needed 5VDC from the supply so voltage regulator can convert the 12VDC to 5VDC. All the I/O signal and data communication are control by the CPU unit with the PIC microcontroller as its brain.

This project use LM35 as the sensor to detect current temperature. The system will have temperature set point adjustment. Set point can be altered according to need by using push button. The current set point will be displayed on the LCD. Motor cooling fan run according to the temperature heating which being control by microcontroller 16F873A.

3.2 Design Circuit & Development

3.2.1 Design the main circuit.

The main circuit has been design. The designs are attach as below:-

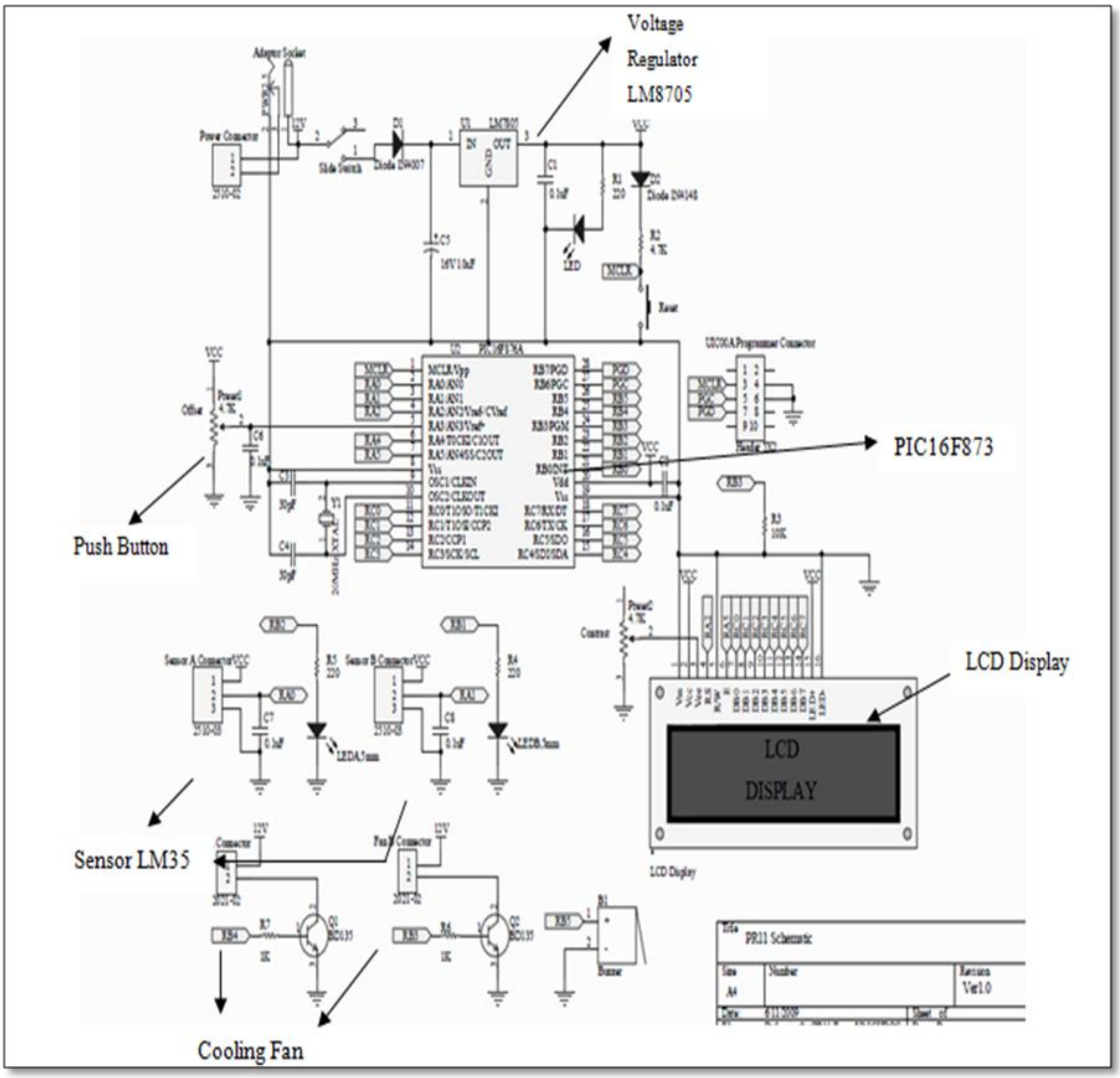

Figure 3.3 : Circuit design

3.2.2 List of Component

Table 3.1 : Component list

No.	Component	Product Code	Unit
1	DC Plug (Adaptor Socket)	CN-HL-2527-B	1
2	Mini Slide Switch (PCB)	SW-SL-2SC-040904	1
3	Diode 1N4007	DI-1N4007	1
4	Diode 1N4148	DI-N44148	1
5	LED 3mm Green	DS-LED-3NG	1
6	LED 5mm Red	DS-LED-5NR	2
7	Ceramic Capacitor 30pF	CP-CC-30pf	2
8	Ceramic Capacitor 0.1uF	CP-CC-0.1UF	5
9	Electrolytic Capacitor 16V 10uF	CP-EC-16-10	1
10	Voltage Regulator +5V	VR-7805	1
11	Crystal H49S (Low Profile) 20Mhz	CR-H49S-20M	1
12	10 Ways Straight Box Header	CN-IDC-BOX-10	1
13	IC Socket-28 pin (slim)	IS-28PIN (S)	1
14	6x6x1 Push Button 2 Pins	SW-PBM-2N-060601	1
15	N6 Trimmer (Horizontal)	RS-N6-4K7-H	2
16	Resistor 1/4W 220R	RS-025W-200R	3
17	Resistor 1/4W 10K	RS-025W-10K	1
18	Resistor 1/4W 4.7K	RS-025W-4K7	1
19	Resistor 1/4W 1K	RS-025W-1K	2
20	Buzzer PCB	SO-BUZZ-PCB	1
21	Temperature Sensor (Celcius)	SN-LM35DZ	2
22	Transistor BD135	TR-BD-135	2
23	IC PIC 16F873A	IC-PIC-16F873A	1
24	2 x 16 character LCD	DS-LCD-JHD 162A	1
25	Straight Pin Header(Male) 16 Ways	CN-PH-M140S	1
26	DC Cooling Fan (0.2A)	FAN-12-060060020	2
27	PR11 PCB	PCB-PR-011	1
28	3mm screw & nut	3mm screw & nut	4
29	AC to DC adaptor	AC to DC adaptor	1

3.2.3 PIC 16F873A

This powerful (200 nanosecond instruction execution) yet easy to program (only 35 single word instruction) CMOS FLASH based 8-bit microcontroller packs Microchip's powerful PIC architecture into an 28-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices. The PIC16F873A features 256 bytes of EEPROM data memory, self programming, an ICD, 2 Comparators, 5 channels of 10-bit Analog to Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface or the 2-wire Inter-Integrated Circuit bus and a Universal Asynchronous Receiver Transmitter (UART). All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

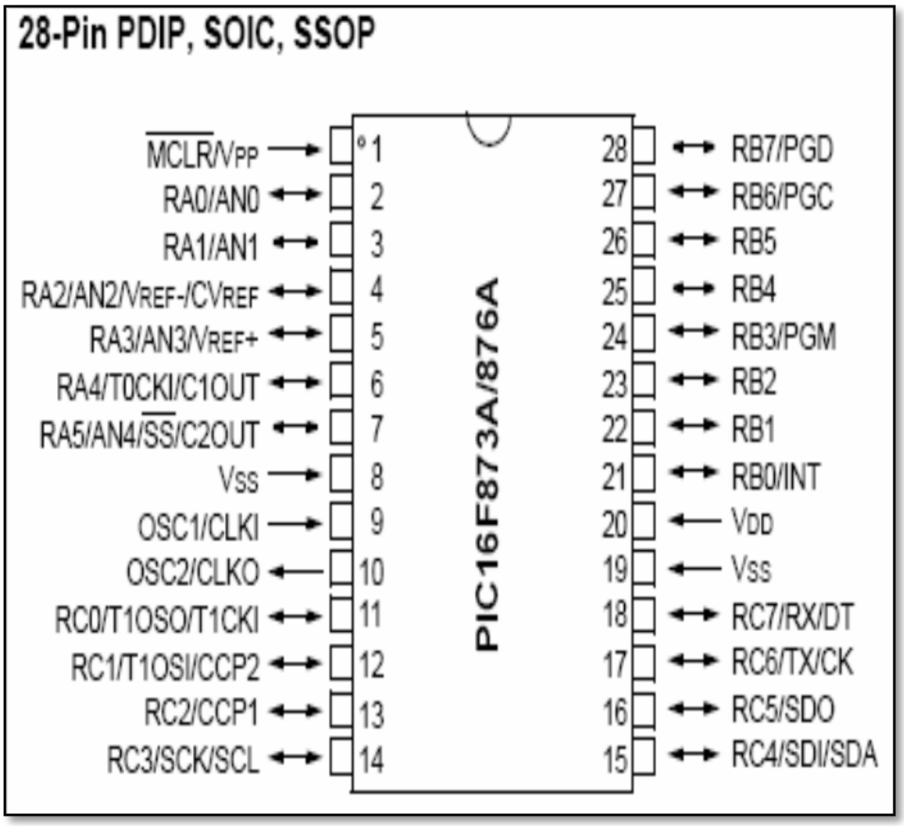

Figure 3.4 : The pin diagram for PIC16F873A

Signal pin (Vout) from LM35 can be connected to either one of analog input pin (AN0-AN4) except AN3 (pin5) . pin 5 (Vref+) from PIC should be given for 1V but ift may has offset, so a variable resistor (VR1) was installed for voltage adjusting. For more stability, a capacitor (104) between the analog signal and GND for every analog input such as signal from LM35 and variable resistor (VR1).

3.2.4 Power supply for circuit

For this project, the voltage range of power source could be given for this circuit board is between 7V and 15V. Higher input voltage will produce more heat at LM7805 voltage regulator. Typical voltage is 12V. There are two type of power connectors on the circuit board, Dc plug 'Adaptor' is for AC-DC adaptor and 2510-02 'Power' is for battery source. Normally AC to DC adaptor can be plugged to 'Adaptor' type connector. LM7805 (1A maximum) will regulate the given voltage to 5V (Vcc) for supplying to the PIC16F873A and pull-up the push button (input). The purpose of using diode (D1) is for circuit protection in case the polarity of the power source is incorrect. Capacitor (C5) and capacitor (C1) is use to stabilize the voltage input and output of the LM7805. Capacitor (C2) is used for reducing the instability of PIC and green LED (small) as power indicator.

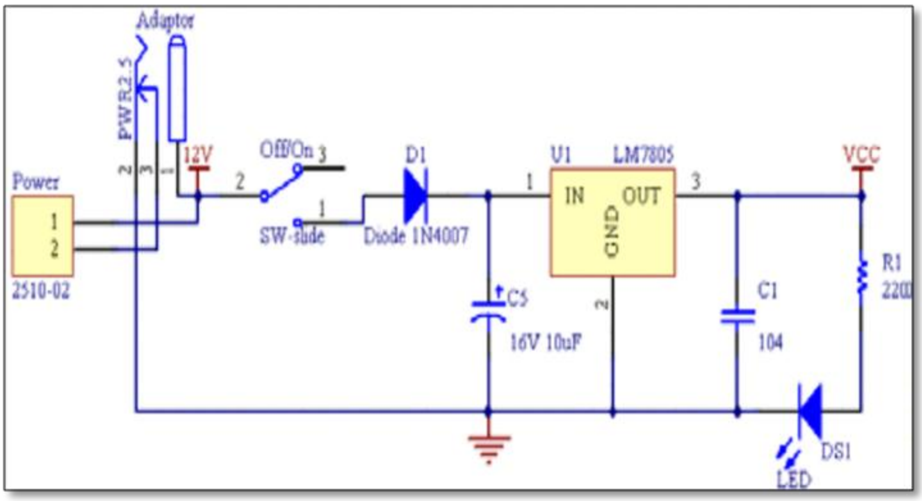

Figure 3.5 : Power supply circuit

3.2.5 Power Transistor (BD135)

BD135 is used for controlling the DC fan with sufficient current. The BD135 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. Parameter BD135 Collector-Base Voltage = 0) Collector-Emitter Voltage = 0) Emitter-Base Voltage = 0) Collector Current Collector Peak Current Base Current Total Dissipation at T amb 25 C Storage Temperature Max. Operating Junction Temperature

Pinning

PIN	Description
1	Emitter
2	Collector, connected to metal part of mounting surface
3	Base

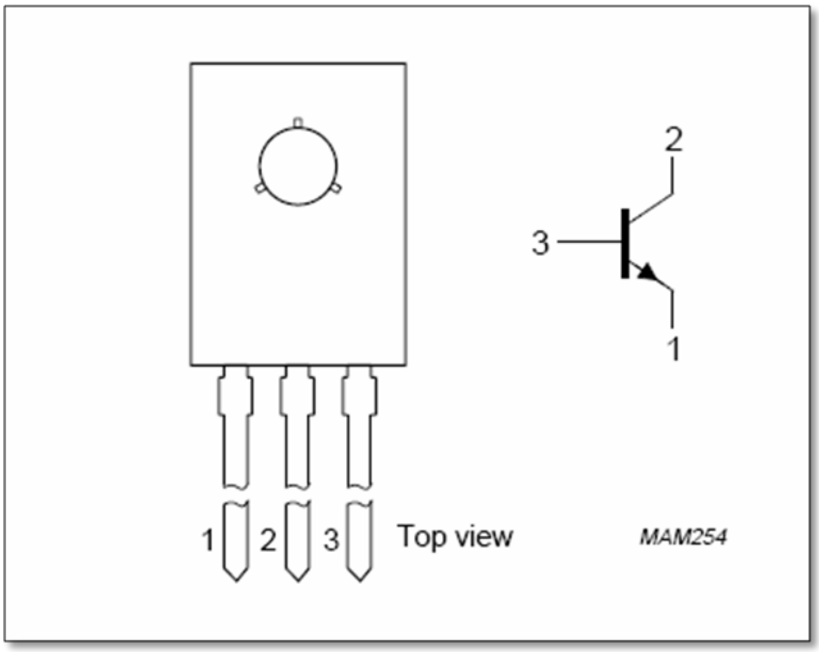

Figure 3.6: Simplified outline (TO-126;SOT32) and symbol.

3.2.6 Interface PIC16F873A with LCD

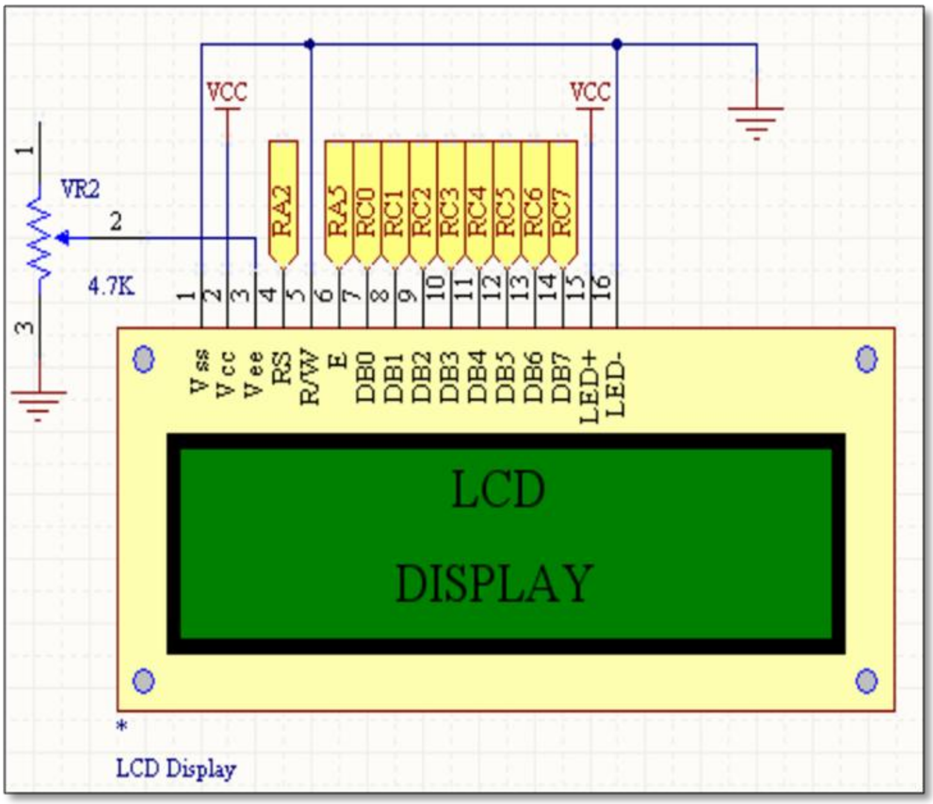

Figure 3.7: The schematic of the LCD display.

An HD44780 LCD is a de facto industry standard liquid crystal display (LCD) display device designed for interfacing with embedded systems. These screens come in a variety of configurations including 8x1, which is one row of eight characters, 16x2, and 20x4. The most commonly manufactured configuration is 40x4 characters, which requires two individually addressable HD44780 controllers with expansion chips. These LCD screens are limited to text only and are often used in copiers, fax machines, laser printers, industrial test equipment, networking equipment such as routers and storage devices. Character LCDs can come with or without backlights, which may be LED, fluorescent, or electroluminescent. Character LCDs use a standard 14-pin interface and those with backlights have 16 pins.

The following table shows the LCD (2X16character) connection:

Table 3.2 : LCD (2X16character) 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	RA2
5	R/W	Select read or write	GND
6	E	Start data read or write	RA5
7	DB0	Data bus pin	RC0
8	DB1	Data bus pin	RC1
9	DB2	Data bus pin	RC2
10	DB3	Data bus pin	RC3
11	DB4	Data bus pin	RC4
12	DB5	Data bus pin	RC5
13	DB6	Data bus pin	RC6
14	DB7	Data bus pin	RC7
15	LED+	Backlight positive input	5V
16	LED-	Backlight negative input	GND

3.2.7 Temperature Sensor - The LM35

By interfacing different types of sensors with our microcontroller we can sense the environment and take decisions, in this way we can create "smart" applications. There are wide varieties of sensors available. In this tutorial we will learn about a popular sensor LM35 which is precision centigrade temperature sensor. It can be used to measure temperature with accuracy of 0.5 Co.

- LM35 by National Semiconductor is a popular and low cost temperature sensor. It is also easily available.
- It has three pins as follows.

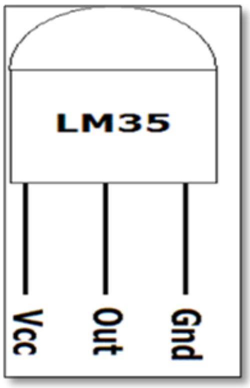

Figure 3.8: LM35 pin configuration

In this project, two LM35s are used for two difference temperature. Vs of the LM35s are given 5V and the Vout pins are connected to AN0 and AN1 (PIC16F873A) separately. The Vcc can be from 4V to 20V as specified by the datasheet. To use the sensor simply connect the Vcc to 5V, GND to GND and the Out to one of the ADC (analog to digital converter channel). The output linearly varies with temperature. The output is10MilliVolts per degree centigrade.

3.2.8 Push Button as Input for PIC

One I/O pin is needed for one push button as input for PIC microcontroller. The connection of the push button to the I/O pin is shown in Figure. The I/O pin should be pull up to 5V using a resistor (with value range 1K-10K) and this configuration will result an active-low input. When the button is pressed, reading of I/O pin will be in logic 0, while when the button is not pressed, reading of that I/O pin will be logic 1.

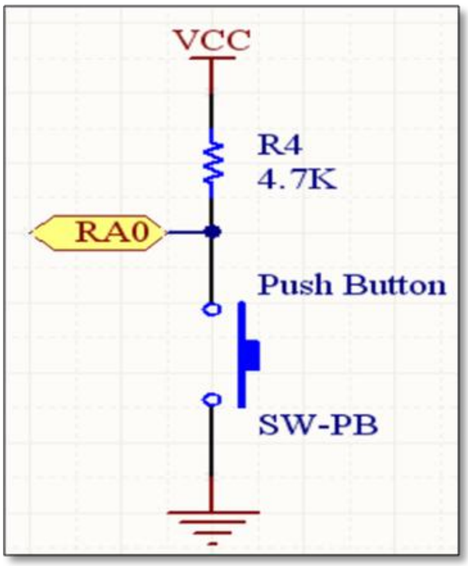

Figure 3.9: Push button configuration

3.2.9 LED as Output for PIC microcontroller

One I/O pin is needed for one LED as output for PIC microcontroller. The connection for a LED to I/O pin is shown in Figure. 3.10. The function of R8 is to protect the LED from over current that will burn the LED. When the output is in logic 1, the LED will ON, while when the output is in logic 0, the Led will OFF.

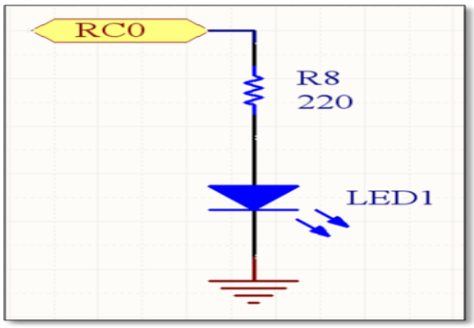

Figure 3.10 : LED schematic

3.2.10 USB PIC Programmer V2009

UP00B is the enhanced version of UP00A. PIC MCU is more low cost and user friendly programmer. Previous USB PIC Programmer, UP00A is obsolete because it cannot support Windows Vista, fail to program many new PIC MCU, further the firmware is not upgradeable. With two ZIP sockets to offer program loading to 8 pin, 18 pin, 28 pin and 40 pin PIC MCU (8 bit) by using Microchip PICKit2 software. It offers a low cost and convenience USB PIC Programmer to interfere with PIC16F873A.

Figure 3.11: USB PIC Programmer V2009

3.3 Software Development

Software development is the most important in this project. C language is used in order to implement fuzzy logic system in the microcontroller.

3.3.1 Fuzzification

Fuzzification involves the conversion of the input or output signals into a number of fuzzy represented values, which are the fuzzy sets. In this project, it is designed that there are one input signals and one output signal for the Fuzzy logic. The input will be having 5 membership function sets respectively.

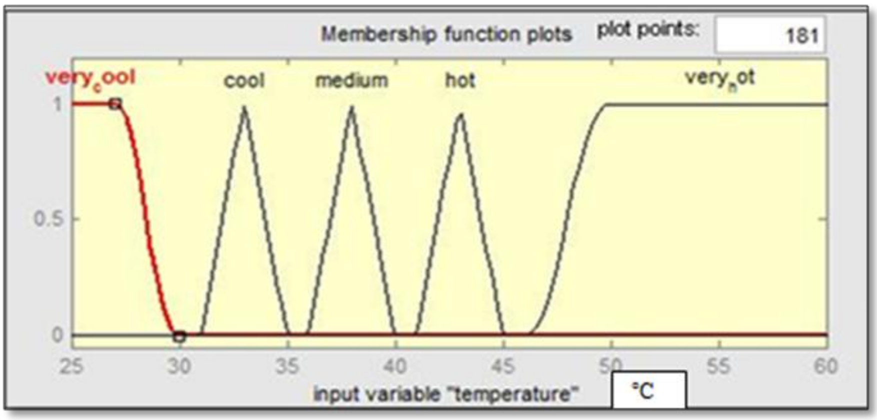

Figure 3.12 : Fuzzy set for input

The fuzzification for the 5 membership functions are :-

Table 3.3 : Input Membership Function

Temperature Range (°C)	Membership Function (MF)
<30°C	Very cool
31-35°C	Cool
36-40°C	Medium
41-45°C	Hot
46 >	Very Hot

3.3.2 Defuzzification

Defuzzification is a mapping from a space of fuzzy control actions defined over an output universe of discourse into a space of non-fuzzy (crisp) control action. This process is necessary because in many practical applications crisp control action is required to actuate the plant. The defuzzifier also performs an output denormalization if normalization is performed in the fuzzification module. This method is only valid for symmetrical output membership functions. The weight average method is formed by weighting each membership function in the output by its respective maximum membership value, z.

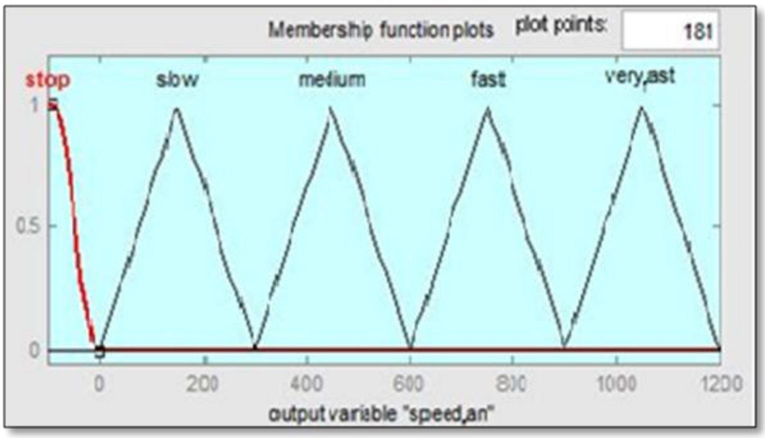

Figure 3.13 : Fuzzy set for output

Table 3.4 : Output Membership Function

Fan Speed (RPM)	Membership Function (MF)
0	Stop
300	Slow
600	Medium
900	Fast
1200	Very fast

3.3.3 Temperature accuracy

To get the actual temperature on LCD display, the equation y= mx+c formula is used to determine the accurate temperature. 29.4 C is the actual temperature using digital thermometer and compare with the circuit display temperature is 60.1 C. Since the boiler heat is 100 C, the LM35 sensor show result 430 C. To get the accurate value temperature, need to find c value.

From the graph, m value is 5.241.

$m = 5.241$

y = desired value in coding.

x = temperature value

$y = mx + c$

$430 = 5.241\ (100) - c$

$c = 94.1$

To find y, for 30 C, 31 C, 35 C, 36 C, 40 C, 41 C, 45 C, 46 C , the formula is used to get the correct temperature value.

Table 3.5 : The coding temperature using formula

x = actual temperature	y = Temperature value in coding
30 C	y = 63.13
31 C	y = 68.371
35 C	y = 89.335
36 C	y = 94.576
40 C	y = 115.54
41 C	y = 120.781
45 C	y = 141.745
46 C	y = 146.986

3.4 Hardware Development

3.4.1 Model proposed

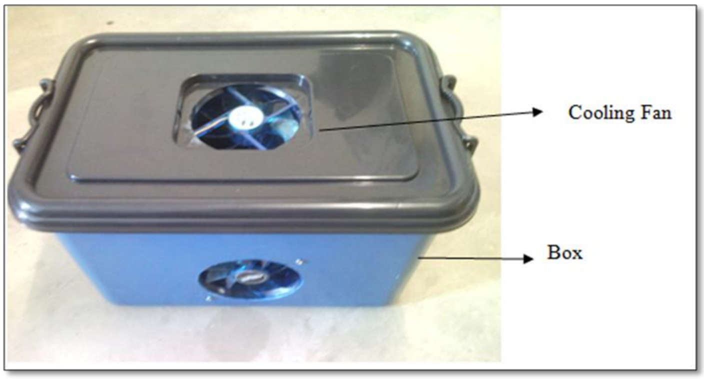

Figure 3.14 Complete model

This is a storage box with a size of 16x11 inches. There are two cooling fan in the model to vent out the hot air and to keep temperature inside the model low. One fan is on the top of the model and another fan is at side of the model.

3.4.2 Interface PIC16F873A with DC Brushless Fan

The current I/O pin from PIC is limited to drive a DC Brushless Fan (0.2A), So Power Transistor (BD135) is required for giving current , Ic of BD135 is 1.5A, which means the DC Brushless Fan greater than 1.5A cannot be driven in this project. The fan size is 120x120x25mm. The fan speed is 1200 RPM. The fan operating Voltage/ VDC from 6-13.8 V and the rated Voltage is 12V. The fan weight is 125g.

Figure 3.15 : 12V DC Cooling Fan

3.4.3 Digital thermometer

This digital thermometer are used to collect data for analysis. Digital thermometer show temperature range around -50C to 80C.

Figure 3.16 : Digital Thermometer

3.4.4 Solar system

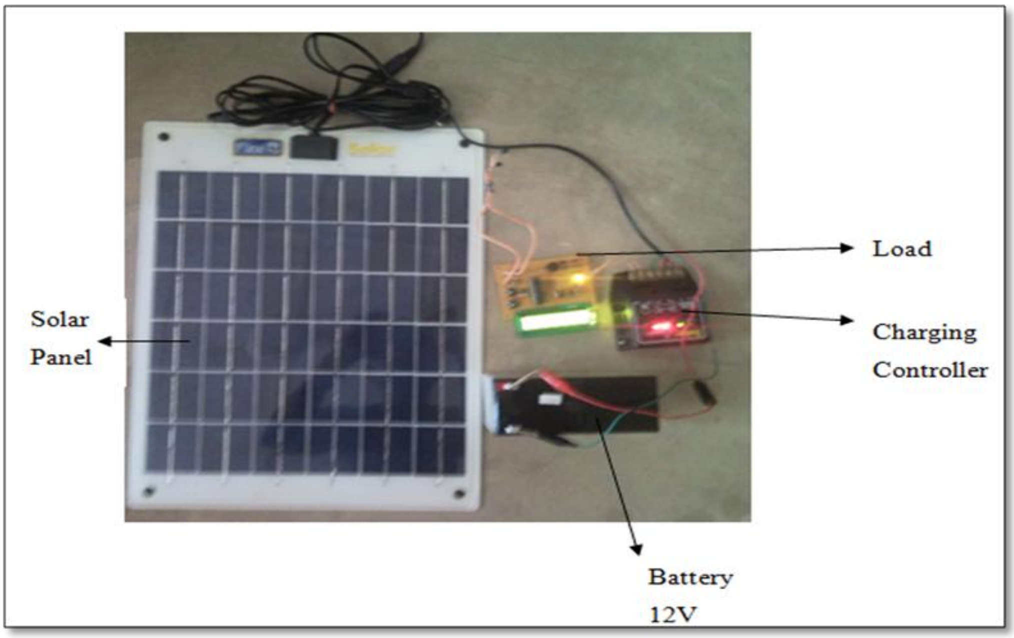

Figure 3.17 : Solar system

The main three components in solar system are solar panel, charging circuit and battery. In this project, model type SFP020 Flexi PV 20W are used to charge batteries via a solar charge controller. DC lights are normally connected to the charge controller. The solar panel be able to deliver this voltage to the battery after power losses and voltage drop in the cables and charge controller and in conditions in which the solar cells operate at a high temperature. Light weight of this panel is 687g.

Charge controller is to protect the battery and ensure it has a long working life without impairing the system efficiency. Charge controllers are used in this project to protect the battery from over-discharge, normally referred to as low voltage disconnect (LVD) that disconnects the battery from the load when the battery reaches a certain depth of discharge (DOD).

In this project, battery Yuasa REC10-12 utilizes the latest advanced technology. Battery are used are REC10-12, 12V. This battery capacity is 10Ah. Battery voltage is 12 V and lead acid technology. The height, width, and depth are 115.5mm and 151mm and 65mm. Battery weight is 3.4 kg. This battery can operate at maximum and minimum temperature at 60C and -20C. The output voltage is 12V.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Result and Analysis

In this chapter, show about the result of the 'Temperature Control Using Fuzzy Logic Techniques' and how it works with the implementation. Fuzzy logic has been program in microcontroller in order to test it.

4.2 Model Proposed

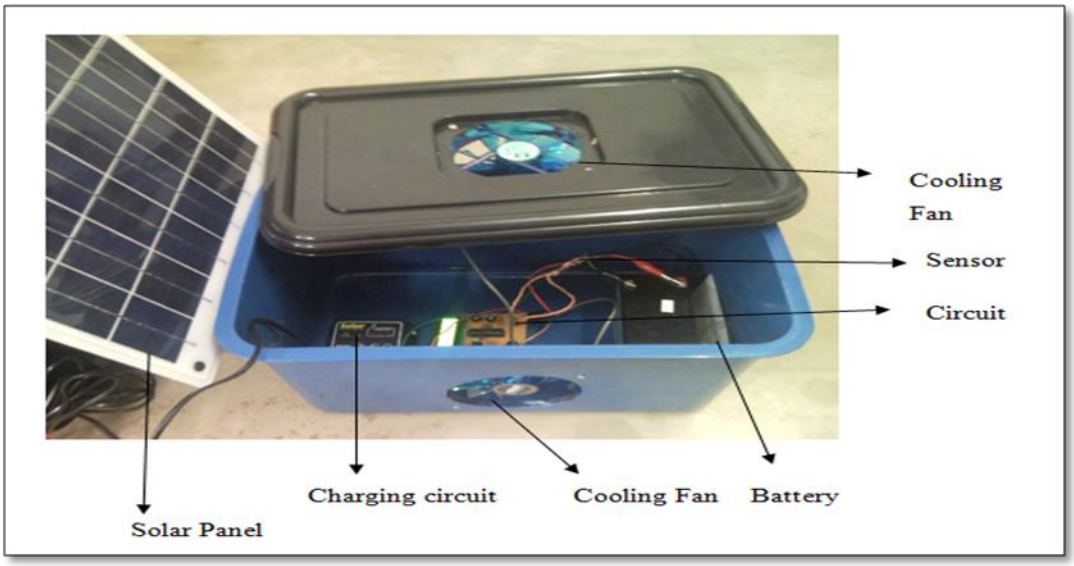

Figure 4.1 : Complete Model of Project

The above figure show the complete model of this project, There are solar panel outside of the model to charge when left the model under the sunlight. Inside the model, there are charging circuit, 12V battery, and the circuit. Temperature sensor is inside the model and the two cooling fan run according to the fuzzy system.

4.3 Results of Temperature interior and exterior vehicle

Temperature inside and outside vehicle has record by measuring using temperature detector to know the temperature value in a car in park condition under sunlight to set the fuzzy rule base. The result has been shown as below :-

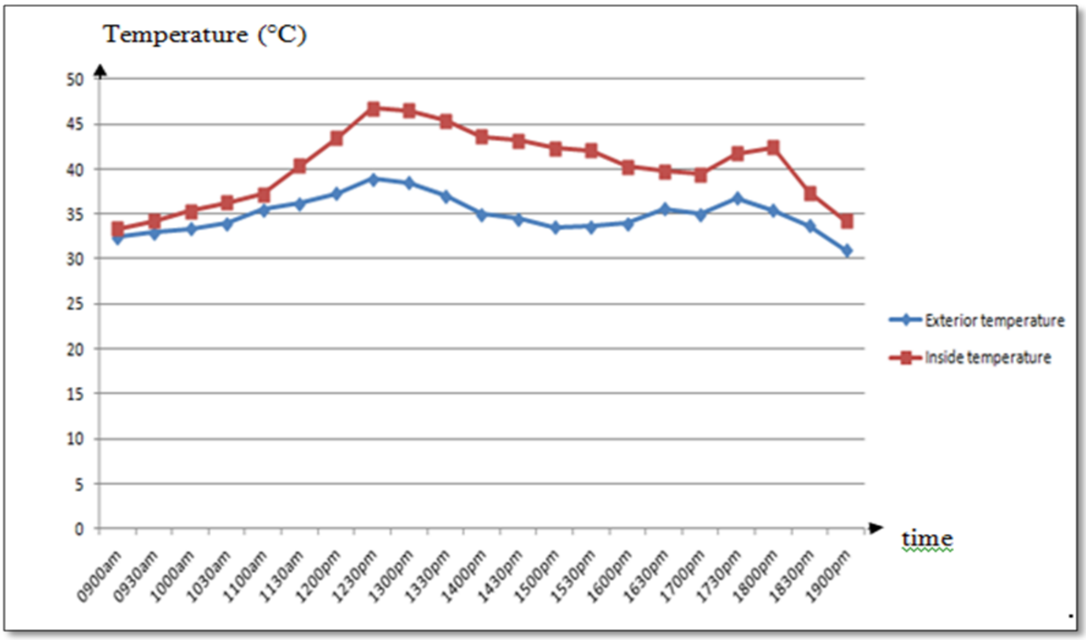

Figure 4.2: Graph result of temperature inside and exterior vehicle

Figure 4.2 show about comparison between the temperature value interior and exterior car which parked at open parking under sunlight 10 hours from morning 9am until evening 7pm. In general, the measurement of the data is taken for few days to get actual hot weather time. From the graph, can indicate that inside vehicle temperature is more heat compare to exterior temperature. This is because, there was no air flow inside the car during in park condition and it can cause humidity. The maximum temperature inside vehicle is 48°C, meanwhile minimum temperature are

33°C. On the other hand, the maximum temperature outside vehicle is 39°C, meanwhile minimum temperature are 31°C. The maximum inside vehicle temperature increase during afternoon time around 12pm. This is because it is the sun will be directly overhead, so we receive direct sun rays, and in the morning the sun rays are slanting ,the same is in evening, so it is hot in afternoon rather than in the mornings or in the evenings. However, in the evening inside temperature is decreasing back to outside temperature and only 5°C different at the end of the day. Its show that the driver and passenger become uncomfortable while entering the car since there were still humidity inside the car.

4.3.1 Results of Temperature interior and exterior Model

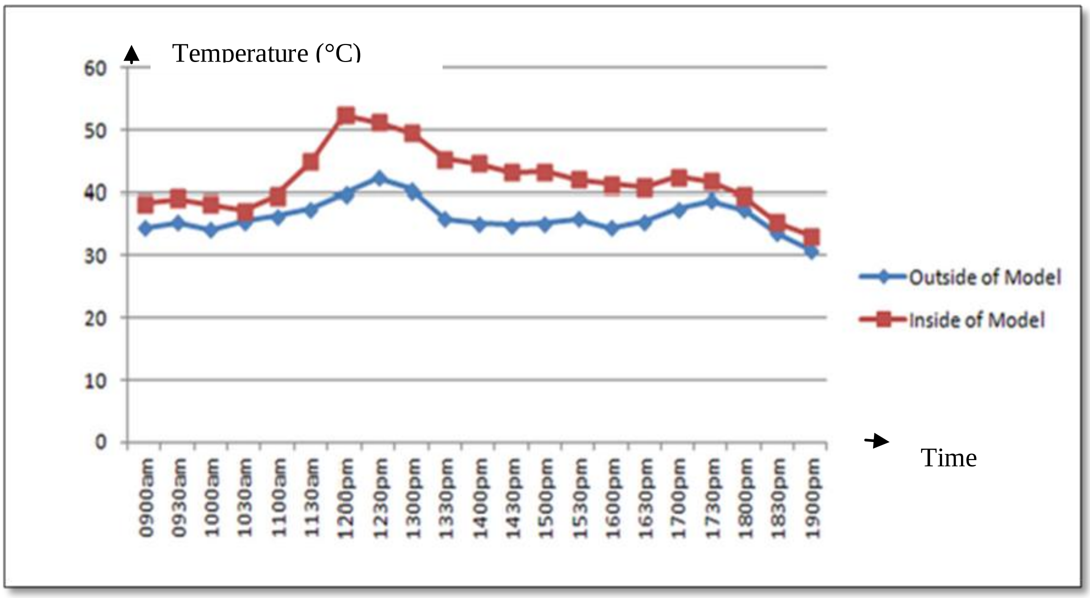

Figure 4.3 : Graph result of temperature inside and outside model

Figure 4.3 show about comparison between the temperature value interior and exterior model which left at open parking under sunlight for 10 hours from morning 9am until evening 7pm. From the graph, can indicate that inside model temperature is more heat compare to exterior temperature. This is because, there was no air flow inside the model and its more small compare to real car size. Therefore, the heat is easier to absorb compare to real vehicle. The maximum temperature inside model is 49.5°C, meanwhile minimum temperature are 33.3°C. On the other hand, the maximum temperature outside model is 42.3 °C, meanwhile minimum temperature are 31°C. The maximum inside vehicle temperature increase during afternoon time around 1pm. This is because it is the sun will be directly overhead, so we receive direct sun rays, and in the morning the sun rays are slanting ,the same is in evening, so it is hot in afternoon rather than in the mornings or in the evenings. However, in the evening inside temperature is decreasing back to outside temperature and only 2 °C different at the end of the day.

4.3.2 Results of Temperature interior and exterior Model with cooling system.

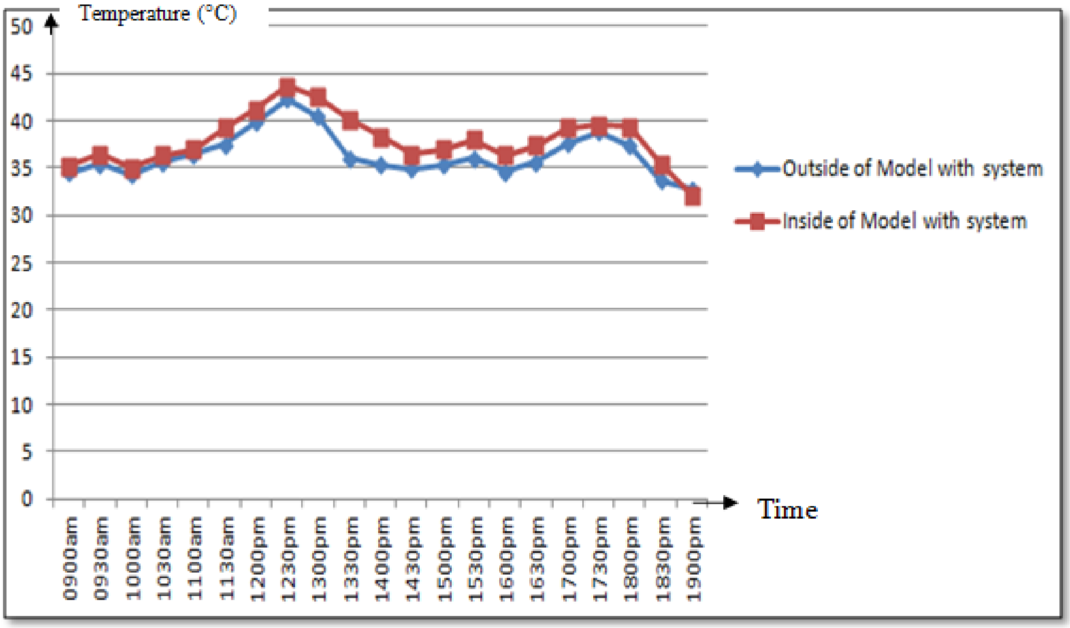

Figure 4.4: Graph result of temperature inside and outside model with cooling system

Figure 4.4 show about comparison between the temperature value interior and exterior model which left at open parking under sunlight 10 hours from morning 9am until evening 7pm. From the graph, can indicate that inside model temperature is more heat compare to exterior temperature. This is because, there was no air flow inside the model and it's more small compare to real car size. Therefore, the heat is easier to absorb compare to real vehicle. The maximum temperature inside model is 43.6°C, meanwhile minimum temperature are 32.1°C. On the other hand, the maximum temperature outside model is 42.3 °C, meanwhile minimum temperature are 32.8°C. The maximum inside vehicle temperature increase during afternoon time around 12.30pm. This is because it is the sun will be directly overhead, so we receive direct sun rays, and in the morning the sun rays are slanting ,the same is in evening, so it is hot in afternoon rather than in the mornings or in the evenings. However, in the evening inside temperature is decreasing back to outside temperature and only 0.7 °C different at the end of the day. As can be seen, during periods when the cooling systems are operate, temperature inside vehicle can be reduced.

4.4 Discussion

This project is using single input single output (SISO) fuzzy logic. The result can be more better if more input used and more variable (MIMO) can be implemented in the program. The results above show that when the current temperature is higher, the cooling fan speed is operating fuzzy to control the inside model temperature and decrease the current temperature inside the model. The system is more effective when there are more point of cooling fan.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Temperature Control Using Fuzzy Logic Technique project is not just a common temperature control, it is a new concept and idea about creating a better system for future. As can be seen, during periods when the ventilation systems are operate, temperature inside vehicle can be reduced. So, the problem like animal and children being severely injured by being left unattended in closed and locked parked car can be avoided.

Even though these project just use single input single output (SISO), the concept of fuzzy is still there. The important is to understand the concept of fuzzy system, how fuzzy work and the way to implement it.

Fuzzy logic was conceived as a better method for sorting and handling data but has proven to be a excellent choice for many control system applications since it mimics human control logic. It uses an imprecise but very descriptive language to deal with input data more like a human operator.

Fuzzy logic does not require precise inputs, is inherently robust, and can process any reasonable number of inputs but system complexity increases rapidly with more inputs and outputs. Simple, plan- language IF X AND Y THEN Z rules are used to describe the desired system response in terms of linguistic variables rather than mathematical formulas. The number of these is depending on the number of inputs, outputs, and the designer's control response goals.

5.2 Recommendation

The temperature control system could be upgraded using more inputs and variable outputs to get the best results in car ventilation system. In this project, usage of more temperature sensor could be a good idea to measure and work in more efficiency. There is much more recommendation for fuzzy logic in future. Today, the practical application of Fuzzy Logic Controller has expanded rapidly due to its incredible flexibility and adaptability. Fuzzy logic is an innovative technology that enables the implementation of 'intelligent' functions in embedded systems.

5.3 Summary

For this chapter, all step and process to develop this project have concluded and analyze. Temperature Control Using Fuzzy Logic Technique is just a project to show the system of fuzzy logic but as always the most important understands about the concept of fuzzy logic.

Basically, the objective and main aim of this project are achieved. From the continuous research and development, fuzzy logic can change the world. In other hand, this project can be improved with more input and variables in order to get the best output.

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APPENDIX A

Programming for Simulation

```
//DEVANDRAN A/L KRISNAN
//EA09009
//DEVELOPMENT OF FUZZY LOGIC CONTROLLER TO CONTROL VEHICLE
TEMPERATURE
//==================include===================================
#include<pic.h>

//===============configuration===============================
__CONFIG (0x3F32);

//===============define IO port==============================
#define     lcd       PORTC
#define     RS        RA2
#define     E         RA5
#define     CHANNEL0   0b10000001   // AN0
#define     CHANNEL1   0b10001001   // AN1
#define     buzzer     RB5
#define     fanA       RB4
#define     fanB       RB3
#define     ledA       RB2
#define     ledB       RB1
```

```
//==============FUNCTION PTOTOTYPE=========================
void e_pulse(void);
void delay(unsigned short i);
void send_char(unsigned char data);
void send_config(unsigned char data);
void lcd_goto(unsigned char data);
void lcd_clr(void);
void dis_num(unsigned long data);
void increment(unsigned long data);
void read_adc(void);
unsigned short read_temp(void);

//====================MAIN==================================
unsigned short result;
unsigned short temp,tempA,tempB;

void main(void)
{
  ADRESH=0;              //clear A/D result
  ADRESL=0;              //clear A/D result

  //setting ADCON1 Register
  ADCON1=0b11000101;        // A/D result right justified,
                    // configure RA2 and RA5 as digital I/O

  TRISA=0b11011011;        //configure PORTA I/O direction
  TRISB=0b00000000;        //configure PORTB as output
  TRISC=0b00000000;        //configure PORTC as output

  PORTA=0;
  PORTB=0;

  while(1)
  {
```

```
send_config(0b00000001);     //clear display at lcd
send_config(0b00000010);     //Lcd Return to home
send_config(0b00000110);     //entry mode-cursor increase 1
send_config(0b00001100);     //diplay on, cursor off and cursor blink off
send_config(0b00111000);     //function set

lcd_goto(0);               //cursor start from beginning

//display character on LCD
send_char(' ');
send_char('T');
send_char('E');
send_char('M');
send_char('P');
send_char('.');
send_char('A');
send_char('=');

lcd_goto(20);              //cursor go to 2nd line of the LCD

//display character on LCD
send_char(' ');
send_char('T');
send_char('E');
send_char('M');
send_char('P');
send_char('.');
send_char('B');
send_char('=');

while(1)                 //infinity loop
{
//sensor A
ADCON0=CHANNEL1;           //CHANNEL1=0b10001001
```

```
lcd_goto(8);

read_adc();

temp=read_temp();
dis_num((temp+94.1)/5.241);
send_char('.');
dis_num(temp%10);
send_char(0b11011111);
send_char('C');
send_char(' ');
send_char(' ');

tempA=temp;

//sensor B
ADCON0=CHANNEL0;          //CHANNEL0=0b10000001

lcd_goto(28);

read_adc();

temp=read_temp();
dis_num((temp+94.1)/5.241);
send_char('.');
dis_num(temp%10);
send_char(0b11011111);
send_char('C');
send_char(' ');
send_char(' ');

tempB=temp;

  if((tempA<63.13)&&(tempB<63.13))
```

```
{
  ledA=0;
  ledB=0;
  fanA=0;
  fanB=0;
 buzzer=0;
}

else
if((tempA>63.13)&&(tempB>63.13)&&(tempA<89.335)&&(tempB<89.335))
 {
  ledA=0;
  ledB=0;
  fanA=0;
  fanB=0;
 buzzer=0;
  delay(7500000000000000);
  ledA=1;
  ledB=1;
  fanA=1;
  fanB=1;
 buzzer=1;
  delay(2500000000000000);
}

else
if((tempA>89.335)&&(tempB>89.335)&&(tempA<115.54)&&(tempB<115.54))
 {
  ledA=0;
  ledB=0;
  fanA=0;
  fanB=0;
 buzzer=0;
  delay(5000000000000000);
```

```
        ledA=1;
         ledB=1;
         fanA=1;
         fanB=1;
      buzzer=1;
       delay(5000000000000000);
    }

    else
if((tempA>115.54)&&(tempB>115.54)&&(tempA<141.745)&&(tempB<141.745))
      {
         ledA=0;
         ledB=0;
         fanA=0;
         fanB=0;
      buzzer=0;
       delay(2500000000000000);
        ledA=1;
         ledB=1;
         fanA=1;
         fanB=1;
      buzzer=1;
       delay(7500000000000000);
    }

    else if((tempA>141.745)&&(tempB>141.745))
      {
         ledA=1;
         ledB=1;
         fanA=1;
         fanB=1;
      buzzer=1;
      }
```

```
      delay(2000);

      }

   }

}



//=================subroutine                    LCD                  setting
=========================

void send_config(unsigned char data)
{
    RS=0;
   lcd=data;
   delay(500);
   e_pulse();
}

void e_pulse(void)
{
   E=1;
   delay(500);
   E=0;
   delay(500);
}

void send_char(unsigned char data)
{
    RS=1;
   lcd=data;
   delay(500);
```

```
  e_pulse();
}


void lcd_goto(unsigned char data)
{
   if(data<16)
  {
     send_config(0x80+data);
  }
  else
  {
     data=data-20;
    send_config(0xc0+data);
  }
}


void lcd_clr(void)
{
  RS=0;
   send_config(0x01);
  delay(600);
}


void dis_num(unsigned long data)
{
  unsigned char hundred_thousand;
  unsigned char ten_thousand;
  unsigned char thousand;
  unsigned char hundred;
  unsigned char tenth;
```

```
hundred_thousand = data/100000;
data = data % 100000;
ten_thousand = data/10000;
data = data % 10000;
thousand = data / 1000;
data = data % 1000;
hundred = data / 100;
data = data % 100;
tenth = data / 10;
data = data % 10;

if(hundred_thousand>0)
{
   send_char(hundred_thousand + 0x30);   //0x30 added to become ASCII code
   send_char(ten_thousand + 0x30);
   send_char(thousand + 0x30);
   send_char(hundred + 0x30);
   send_char(tenth + 0x30);
   send_char(data + 0x30);
}

else if(ten_thousand>0)
{
   send_char(ten_thousand + 0x30);   //0x30 added to become ASCII code
   send_char(thousand + 0x30);
   send_char(hundred + 0x30);
   send_char(tenth + 0x30);
   send_char(data + 0x30);
}
else if(thousand>0)
{
    send_char(thousand + 0x30);   //0x30 added to become ASCII code
   send_char(hundred + 0x30);
   send_char(tenth + 0x30);
```

```
    send_char(data + 0x30);
  }
  else if(hundred>0)
  {
     send_char(hundred + 0x30);   //0x30 added to become ASCII code
    send_char(tenth + 0x30);
    send_char(data + 0x30);
  }
  else if(tenth>0)
   {
    send_char(tenth + 0x30);   //0x30 added to become ASCII code
    send_char(data + 0x30);
  }
  else send_char(data + 0x30);   //0x30 added to become ASCII code
}

void increment(unsigned long data)
{
  unsigned short j;
  for(j=10;j>0;j--)
  {   lcd_goto(32);
    data=data+1;
    dis_num(data);
    delay(10000);
  }

}

//=================subroutine ADC=======================

void read_adc(void)
{
  unsigned short i;
  unsigned long result_temp=0;
```

```
  for(i=2000;i>0;i-=1)        //looping 2000 times for getting average value
  {
    GO_DONE = 1;              //ADGO is the bit 2 of the ADCON0 register
    while(GO_DONE==1);            //ADC start, ADGO=0 after finish ADC progress
    result=ADRESH;
    result=result<<8;         //shift to left for 8 bit
    result=result|ADRESL;      //10 bit result from ADC

    result_temp+=result;
  }
  result = result_temp/2000;      //getting average value

}

unsigned short read_temp(void)
{
  unsigned short temp;
  temp=result;
  return temp;

}

//=================subroutine DELAY========================
void delay(unsigned short i)
{
  for(;i>0;i--);
}
```

APPENDIX B

DATA SHEET

MICROCHIP

PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

High-Performance RISC CPU:

- Only 35 single-word instructions to learn
- All single-cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input DC – 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during Sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) – 8 bits wide with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (V_{REF}) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Special Microcontroller Features:

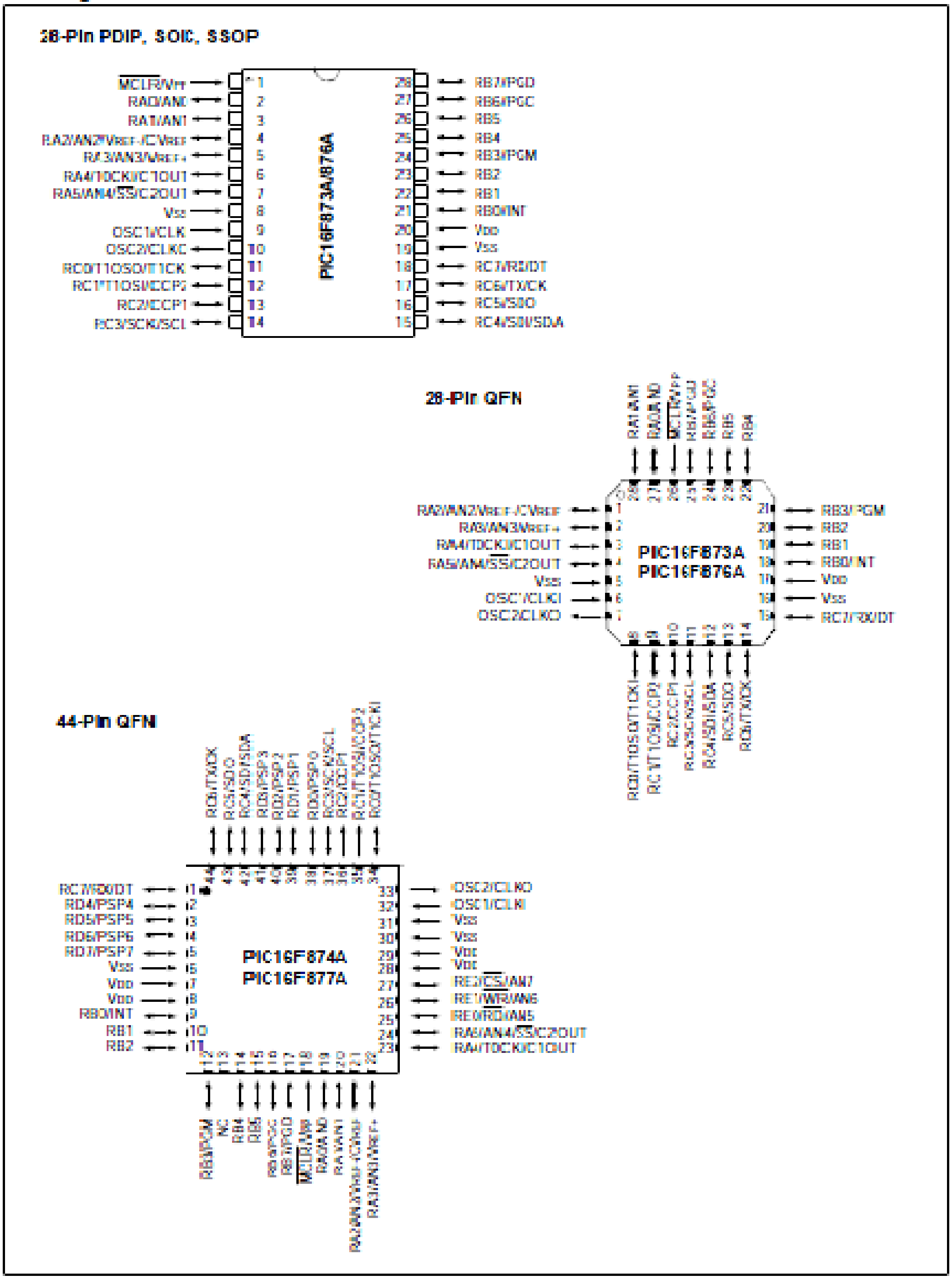
- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

CMOS Technology:

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low-power consumption

Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I²C			
PIC16F873A	7.2K	4096	192	128	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2/1	2
PIC16F876A	14.3K	8192	368	256	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

Pin Diagrams



National Semiconductor

July 1999

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

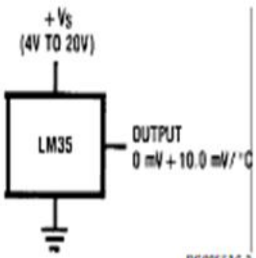
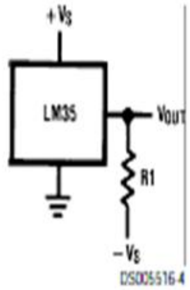


FIGURE 1. Basic Centigrade Temperature Sensor (+2˚C to +150˚C)



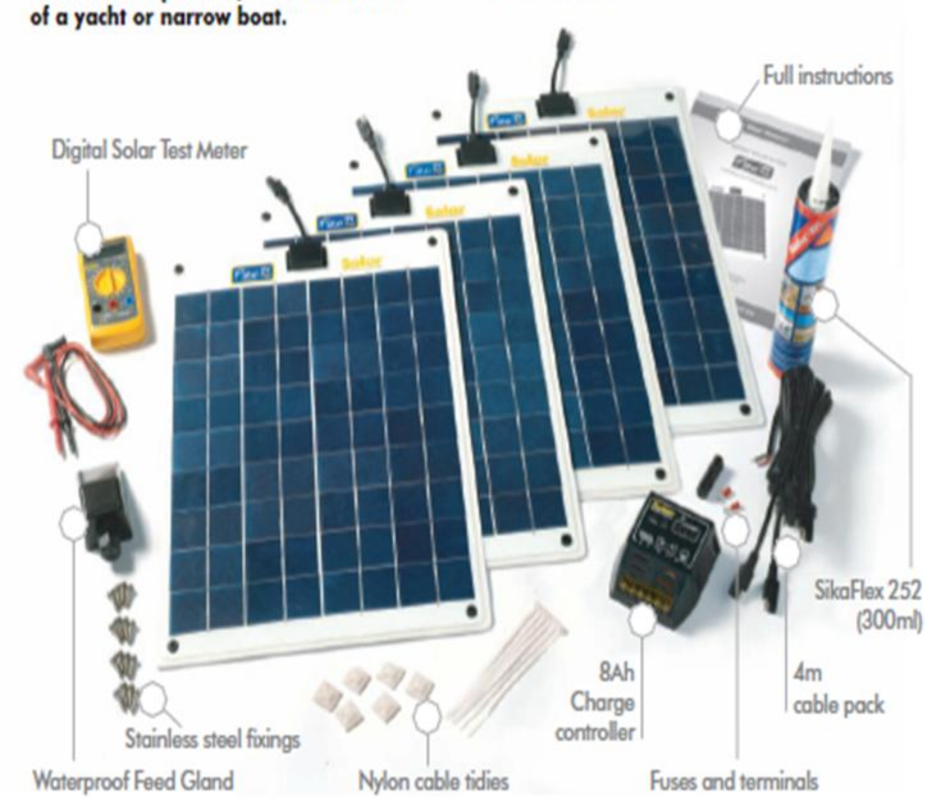
Choose $R_1 = -V_S/50\ \mu A$

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

The Flexi PV range of roof/decktop kits provide everything needed to semi-permanently fit this solar system to the roof of a camper van, caravan or deck of a yacht or narrow boat.

Designed to be quick and simple to attach, these smart roof/decktop kits will give trouble-free power even in the wildest of conditions.



(The kit shown is SFPRT080)

The Flexi PV Range

Kits are available with three levels of equipment:

1. As a Basic Kit, which includes the panel(s), all necessary cabling, and a fuse
2. As the Basic Kit, but including a Charge Controller (apart from SFP010)
3. As a Roof/Decktop Kit, which is the Basic Kit plus Charge Controller, plus a full fixing kit as above

Power	Part Number			Size	Weight	Amps/Hr	Amps/Day	Typical usage	Charge Controller required**
	Basic Kit	Inc. Charge Controller	Roof/decktop Kit						
10W	SFP010	N/A	SFPRT010	357 x 268 x 2mm	0.4kg	0.63	Up to 4.41	**Boats/motorhomes/caravans:** lighting, battery maintenance, waterpump; **Camping/expedition:** limited mobile/TV; **Domestic/Field:** power tool charging, electric fence power	No†
20W	SFP020	SFP020MA	SFPRT020	495 x 351 x 2mm	0.7kgs	1.27	Up to 8.89	**Boats/motorhomes/caravans:** lighting, waterpump, TV; **Camping/expedition:** mobile/laptop/TV; **Domestic:** TV, electric gate motor	Yes - 4 Ah
30W	SFP030	SFP030MA	SFPRT030	357 x 268 x 2mm & 495 x 351 x 2mm	1.1kg	1.9	Up to 13.30	**Boats/motorhomes/caravans:** Ideal for use where power consumption is mainly limited to running the interior lights and water pump and/or use is during the summer months. **Camping/expedition:** Limited laptop/mobile/TV etc	Yes - 8 Ah
40W	SFP040	SFP040MA	SFPRT040	495 x 351 x 2mm – 2 pieces	1.4kgs	2.54	Up to 17.78	**Boats/motorhomes/caravans:** As per the 30W kit but for extended use during Spring, Summer and Autumn. **Camping/expedition:** Laptop/TV/mobiles etc	Yes - 8 Ah
60W	SFP060	SFP060MA	SFPRT060	495 x 351 x 2mm – 3 pieces	2.1kg	3.81	Up to 26.67	**Boats/motorhomes/caravans:** Spring-Autumn power for long term trip – lighting, multiple laptop, waterpump, TV etc **Camping/expedition:** Multiple laptop/TV/mobiles etc; suitable for Spring-Autumn base camp power	Yes - 8 Ah
80W	SFP080	SFP080MA	SFPRT080	495 x 351 x 2mm – 4 pieces	2.8kgs	5.08	Up to 35.56	**Boats/motorhomes/caravans:** As 60W but suitable for year-round use **Camping/expedition:** As 60W but suitable for year-round use	Yes - 8 Ah

REC10-12

Reliability is your Security

Yuasa REC10-12 utilises the latest advanced design Oxygen Recombination Technology. Yuasa have applied their 80 years experience in the lead acid battery field to produce the optimum design of Sealed Lead Acid batteries.

FEATURES

- Can be used to help achieve BSEN50131 where longer autonomy is required.
- Same foot print as NP7-12 but increased capacity.
- Superb recovery from deep discharge.
- Electrolyte suspension system.
- Gas Recombination.
- Multipurpose: Float or Cyclic use.
- Usable in any orientation (except continuous inverted).
- Superior energy density.
- Lead calcium grids for extended life.
- Manufactured World wide.
- Application specific designs.

Technical Features

Sealed Construction
Yuasa's unique construction and sealing technique ensures no electrolyte leakage from case or terminals

Electrolyte Suspension System
REC batteries utilize Yuasa's unique electrolyte suspension system incorporating a microfine glass mat to retain the maximum amount of electrolyte in the cells. The electrolyte is retained in the separator material and there is no free electrolyte to escape from the cells. No gels or other contaminants are added.

Control of Gas Generation
The design of Yuasa's REC batteries incorporates the very latest oxygen recombination technology to effectively control the generation of gas during normal use.

Low Maintenance Operation
Due to the perfectly sealed construction and the recombination of gasses within the cell, the battery is almost maintenance free.

Operation in any Orientation
The combination of sealed construction and Yuasa's unique electrolyte suspension system allows operation in any orientation, with no loss of performance or fear of electrolyte leakage. (Excluding continuous use inverted)

Valve Regulated Design
The batteries are equipped with a simple, safe low pressure venting system which releases excess gas and automatically reseals should there be a build up of gas within the battery due to severe overcharge. Note. On no account should the battery be charged in a sealed container.

Lead Calcium Grids
The heavy duty lead calcium alloy grids provide an extra margin of performance and life in both cyclic and float applications and give unparalleled recovery from deep discharge.

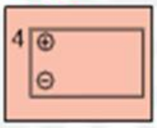
Long Cycle Service Life
Depending upon the average depth of discharge, over a thousand discharge/charge cycles can be expected.

Float Service Life
The expected service life is seven years in float standby applications at 20°C.

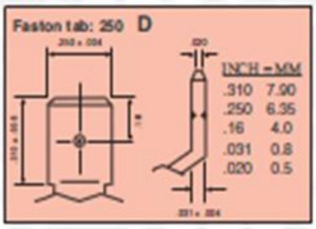
Separators
The use of the special separator material provides a very efficient insulation between plates preventing inter-plate short circuits and prohibiting the shedding of active materials.

Long Shelf Life
The extremely low self discharge rate allows the battery to be stored for extended periods up to one year at normal ambient temperatures with no permanent loss of capacity.

Layout



Terminals



General Specifications

Nominal Capacity (Ah)	REC10-12
20hr to 1.75vpc 30°C	10.0
10hr to 1.75vpc 20°C	9.3
5hr to 1.70vpc 20°C	8.5
1hr to 1.60vpc 20°C	6.0
Voltage	12
Int. Resistance (m.Ohms)	<20
Maximum discharge (A)	40
Short Circuit current (A)	360
Dimensions (mm)	
Length	151
Width	65
Height overall	115.5
Weight (Kg)	3.4
Terminal	A
Layout	4
Terminal Torque Nm	-