

**HEAT AND RAIN DETECTION SYSTEM FOR POWER WINDOW IN  
VEHICLE**

By

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**FINAL PROJECT REPORT**

Submitted to the Electrical & Electronics Engineering Programme  
in Partial Fulfillment of the Requirements  
for the Degree  
Bachelor of Engineering (Hons)  
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# CERTIFICATION OF APPROVAL

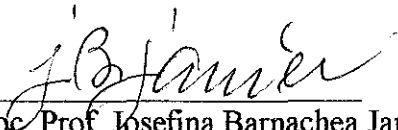
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A project dissertation submitted to the  
Electrical & Electronics Engineering Programme  
Universiti Teknologi PETRONAS  
in partial fulfilment of the requirement for the  
Bachelor of Engineering (Hons)  
(Electrical & Electronics Engineering)

Approved:



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TRONOH, PERAK

June 2008

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

A handwritten signature in black ink, appearing to read 'Mohd Zulkifli Bin Hamzah', is written over a horizontal line.

MOHD ZULKIFLI BIN HAMZAH

## **ABSTRACT**

The primary objective of his project was to construct 'Heat and Rain Detection System for Power Window in Vehicle'. The system was composed of five major modules which were heat sensor module, rain sensor module, microcontroller module, power supply module and motor module. In a hot day, when the temperature inside the car reaches at certain level, the heat sensor will send an input signal to a microcontroller to roll down the power window by one inch in order to let the hot air flow outside. For the rain detection system, it will be activated when it detects rain water. This sensor then sends an input signal to the microcontroller, which in turn sends an output signal to drive the motor to close the window. This innovation for power window mechanism will give some values to the car owner and automobile industry especially to country that its weather is fairly hot and humid all year.

## **ACKNOWLEDGEMENTS**

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## LIST OF ABBREVIATIONS

PIC	Programmable Interface Controller
IC	Integrated Circuit
RTD	Resistive Temperature Devices
TC	Thermo Couple
VDC	Voltage Direct Current
PC	Personal Computer
CPU	Central Processing Unit
I/O	Input/Output
RAM	Random Access Memory
FYP	Final Year Project
NO	Normally Open
NC	Normally Close
C	Common

# CHAPTER 1

## INTRODUCTION

### 1.1 Background of Study

Power windows or electric windows are automobile windows which can be raised and lowered by depressing a button or switch, as opposed to using a hand-turned crank handle. The first electric power windows were introduced around 1946 by Lincoln. These windows are driven by a small electric motor inside the door and have come to be universal in the industry. Prior to that date, in the few vehicles offering this feature, the windows were driven by hydraulics or off the engine vacuum [1]. Power windows are usually inoperable, when the car is not running, as the electrical system is not 'live' once the ignition has been turned off. However, many modern cars have a time delay feature, first introduced by Cadillac in the 1980s, and called retained accessory power. This allows operation of the windows and some other accessories for ten minutes or so after the engine is stopped. Another fairly recent innovation, pioneered by Nissan at about the same time is the express-down window, which allows the window to be fully lowered with one tap on the switch, as opposed to holding the switch down until the window retracts [1].

### 1.2 Problem Statement

Malaysia's position in the equatorial zone guarantees a classic tropical climate with relative humidity levels usually around 90%. Weather is fairly hot and humid all year round (with the exception of the cooler climes of the central highlands) averaging 30 °C in the daytime, with short intense showers almost daily. Malaysia's climate is dominated by the effect of two monsoons or "rainy seasons", which affect different parts of Malaysia to varying degrees. The north-east monsoon blows between October and March and from May to September Malaysia is affected by the south-west monsoon. Heavier rainfall is experienced in spring and autumn when the

monsoon changes direction. Mornings are usually hot and sunny with showers in the afternoon [3].

Therefore, a hot and a rainy day might happen at anytime. The author decided to develop a system for power window in vehicle that will operate automatically depending on its surrounding. In hot day, when the temperature inside the car is extremely high, a certain car parts especially rubber-made accessories might get damaged. This problem may happen when the car is left in an open area and being exposed by sunlight for a long period. A child or baby who is left alone in this condition might get a serious injury or even die. In United Arab Emirates, a three-year-old boy died from the heat after locking himself in a parked car. The boy sneaked into his father's car in the city of al-Ain at noon when the temperature averages around 40°C [4]. Meanwhile, when it rains and car window is left open, the rain water may get inside the car and in this condition, if left for a long period it may damage the car accessories including driver or passenger seats. If the seats get soaked, this might be a big problem to the car owner since it will be hard to get it dried back. Furthermore, this problem will produce an inconvenient smell when people get inside the car. Hence, this project has certain value because its objective is to avoid the above mentioned incidents which are very common in Malaysia and countries that are fairly hot and humid all year.

### **1.3 Objectives and Scope of Study**

#### ***1.3.1 Objectives of the Project***

The intention is to develop power window system to an automatic control and monitoring even the driver is not around. The system will monitor two variables which are the temperature inside the car and the rain water at outside of the car. The main goal of the heat and rain detection system for power window in vehicle is to give the driver the convenience of having his or her car window be opened or closed in the event of rain and in hot day. In hot day, the car power window will open for one inch automatically to reduce hot air. The window will be set to open one inch to

avoid any unwanted occurrence from the outsider. In rainy day, the open car power window will close automatically in order to avoid rain water from getting inside of the car.

### ***1.3.2 Scope of Study***

To accomplish the entire project, the system is distributed into several modules. The major modules and components for this project will be:

- Rain sensor module
  - This module will be the part of detecting rain water in the event of rain.
- Temperature sensor module
  - This module will be the part of detecting excessive temperature inside the car in hot day.
- Power supply module
  - To supply the standard 5VDC electronic circuit and components such as microcontroller. Voltage regulator will be used to step down the 12VDC voltage from car battery to 5VDC.
- PIC microcontroller is used as the brain of the system to process the input and output.
- Limit switch
  - When the window strikes the limit switch, it will give the input to microcontroller to stop the stepper motor rotation.

Since this project is a development towards power window system, therefore this system is only limited to automobile or vehicles that have 2-door or 4-door power window mechanism only. This system is more appropriate and effective to be applied to car in the country where its weather is fairly hot and humid all year.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Power Supply Module**

Every electronics circuit requires a power supply to operate. The required power can be provided from a battery, or the main voltage can be used and then reduced to the required level before it is used in the circuit. The standard power supply voltage in digital electronic circuits is 5VDC and this is the voltage which the PIC microcontrollers are most operated.

The power supply module is needed to connect to car battery and convert 12 VDC to 5VDC in order to power the microcontroller and other electronic components. In addition, this module is needed to provide circuit protection against incorrect setup and voltage spikes from the vehicle during ignition. A voltage regulator will be used to step the voltage down to 5VDC.

As stated in PIC basic Project by Dogan [5], a voltage regulator circuit is used to convert the 12VDC voltage to 5VDC, independent of the current drawn from the supply. A basic voltage regulator circuit consists of a regulator integrated circuit and filter capacitor. Figure 1 shows the low-cost voltage regulator circuit using the 78L05-type voltage regulator IC (see Figure 2 and Figure 3), and two filter capacitors. 78L05 is a 3-pin IC with a maximum current capacity of 100mA. One of the pins of 78L05 is connected to the +V terminal of the battery in parallel with a 0.33  $\mu$ F capacitor. One of the pin is connected to the -V terminal of the battery. The third pin provides the 5V output and 0.01  $\mu$ F capacitor should be used in parallel with this pin. In applications where a larger current is required, the 78L05 regulator IC can be used (refer to Appendix A).

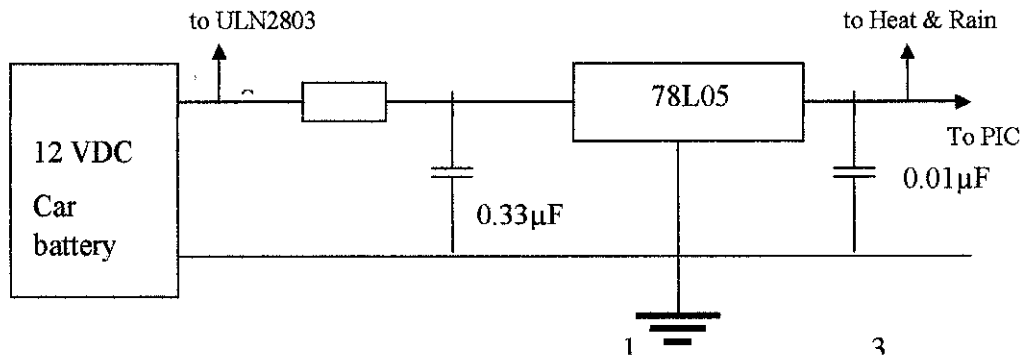


Figure 1 Circuit Diagram of the +5V Voltage Regulator [5]

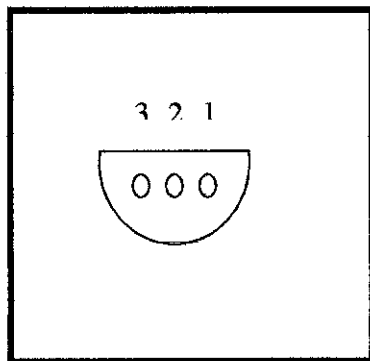


Figure 2 78L05 Bottom View [5]

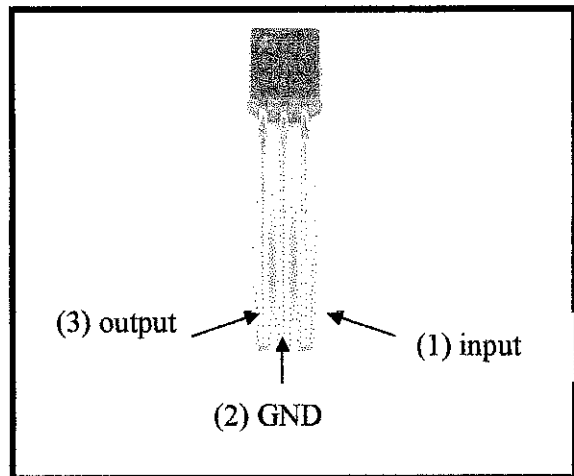


Figure 3 78L05 Voltage Regulator [5]

## 2.2 Temperature Sensor

Many methods have been developed for measuring temperature. Most of these rely on measuring some physical property of a working material that varies with temperature. One of the most common devices for measuring temperature is the glass thermometer. Temperature can be measured via a diverse array of sensors. All of them infer temperature by sensing some change in a physical characteristic. Six types with which the engineer is likely to come into contact are thermocouples, resistive temperature devices (RTDs and thermistors), infrared radiators, bimetallic devices, liquid expansion devices, and change-of-state devices [6].

### 2.2.1 LM35

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The sensor circuitry is sealed and not subject to oxidation. It generates a higher output voltage than thermocouples and may not require the output voltage be amplified. The LM35 (see Figure 4) 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  $\pm \frac{1}{4}$  °C at room temperature and  $\pm \frac{3}{4}$  °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  $\mu$ A 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°C to +150°C temperature range, while the LM35C is rated for a -40°C to +110°C range (-10°C 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-202 package [7]. Refer to Appendix B for LM35 datasheet.



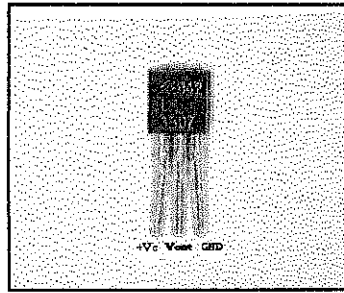


Figure 4 LM35 - Integrated Circuit Temperature Sensor [7]

### 2.3 Microcontroller

Microcontrollers are single-chip computer consisting of CPU (central processing unit), data and program memory, serial and parallel I/O (input/output), timers, external and internal interrupts, all integrated into a single chip that is very cheap in the market. Most microcontrollers operate with the standard logic voltage of 5VDC. Since this project will be using the existing 12VDC car battery, a voltage regulator needs to be used to reduce the voltage to 5VDC to supply the microcontroller [5].

Intelligence of the robot lies in the complex and lengthy algorithm uses in microcontroller. It is not easy to implement such algorithm if there is no good support from programming side. In PIC Microcontroller Project Book by Iovine J. [8] has listed down the advantages of using microcontroller. Some of it are microcontroller which is widely used because of its inexpensive and work as brain of the robot. Apart from that, microcontroller is capable to store and run program.

Microcontroller also has the ability to perform math and logic function, which allow it to understand the sophisticated logic and electronics circuits. In the book "PIC Microcontroller for beginners, too!" [9] stated that microcontroller has memories which functions to store data. The microcontroller is the component that makes the robot intelligent. It also accepts high level programming language such as C. In this project, the microcontroller will take current inputs from temperature sensor, rain sensor and limit switch. The output of the microcontroller will be sent to the motor driver to control the stepper motor rotation. The microcontroller will act as

the brain of the system and it will be programmed by using MPLAB or C language. The time of the motor to run and its algorithm will be programmed in this microcontroller. The possible microcontroller that can be used for this project is PIC 16F877.

PIC is a family of Harvard architecture microcontrollers made by Microchip Technology. It's derived from the PIC1650 which originally developed by General Instrument's Microelectronics Division. The name PIC was originally an acronym for "Programmable Intelligent Computer". However, PIC is generally regarded that stands for Peripheral Interface Controller [10]. PICs privilege are their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and provide serial programming and re-programming with flash memory capability [11]. PIC16F877 as attached in Appendix C is one of the most popular PIC microcontrollers.

It's consist of 40 pin device and offers 8k x 14 words Flash Program Memory, 368 bytes RAM and 256 bytes EEPROM. There are 33 I/O pins where each pin can source or sink 25 mA current. Additionally, the device contains of 3 timers and a watchdog timer with internal oscillator [12]. Other features of the PIC16F877 have been simplified in the Table 1.

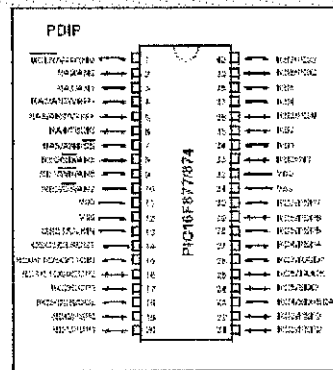


Figure 5 Microcontroller PIC16F877 Pin Configuration [12]

Table 1 Features of Microcontroller, PIC16F877 [12]

Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F877
Operating Frequency	DC - 20 MHz
FLASH Program Memory (14-bit words)	8K
RAM Data Memory (bytes)	368
EEPROM Data Memory (bytes)	256
Interrupts Capability	14 Source
I/O Ports	Ports A,B,C,D,E
I/O Pins	33
Timers	3
Serial Communications	MSSP, USART
Parallel Communications	PSP
Operating Voltage Range	2.0V to 5.5V
High Sink / Source Current	25 mA

## 2.4 DC Motor Module

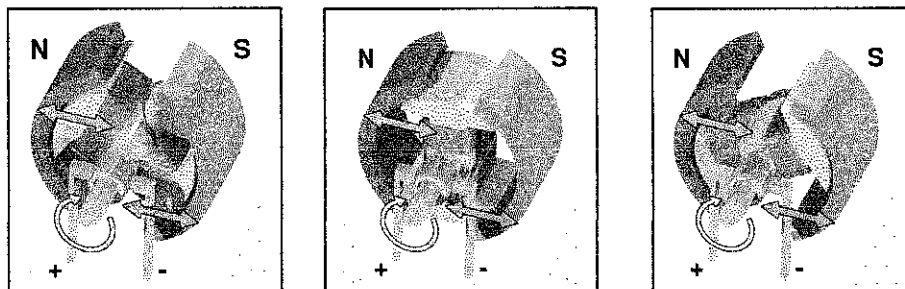


Figure 6 Two Poles DC Motor Operations [13]

A DC motor is an internally commutated which designed to be run with existence of DC power source. When the coil is powered, a magnetic field is generated around the armature. The left side of the armature is pushed away from the left magnet and drawn toward the right, causing rotation. When a current passes through the coil wound around a soft iron core, the side of the positive pole is acted

upon by an upwards force, while the other side is acted upon by a downward force [13].

According to Fleming's left hand rule, the forces cause a turning effect on the coil, making it rotate. To make the motor rotate in a constant direction, "direct current" commutators make the current reverse in direction every half a cycle thus causing the motor to rotate in the same direction [13].

The problem facing by the motor shown above is when the plane of the coil is parallel to the magnetic field; i.e. the torque is ZERO-when the rotor poles or displaced 90 degrees from the stator poles. The motor would not be able to start in this position, but the coil can continue to rotate by inertia. However, unlike the demonstration motor above, DC motors are commonly designed with more than two poles which are able to start at any position, and do not have any position where current can flow without producing electromotive power [13].

## **2.5 Stepper motor**

The initial plan of this project is to use power window motor. However, since the requirement of this project is to control window be opened (one inch), so it is better to use a motor which can be controlled precisely. Stepper motor is a good choice whenever controlled movement is required. It can be used to advantage in applications because stepper motor is capable to control rotation angle, speed, position and synchronism. Because of the inherent advantages listed previously, stepper motors have found their place in many different applications. Some of these include printers, plotters, high-end office equipment, hard disk drives, medical equipment, fax machines, automotive and many more. So, stepper motor (see Figure 7) is the most suitable option for this project because of [14]:

- Easy to interface to digital controllers
- Excellent response to starting/stopping/reversing.

- Precise positioning and repeatability of movement since good stepper motors have an accuracy of 3 – 5% of a step and this error is non cumulative from one step to the next.

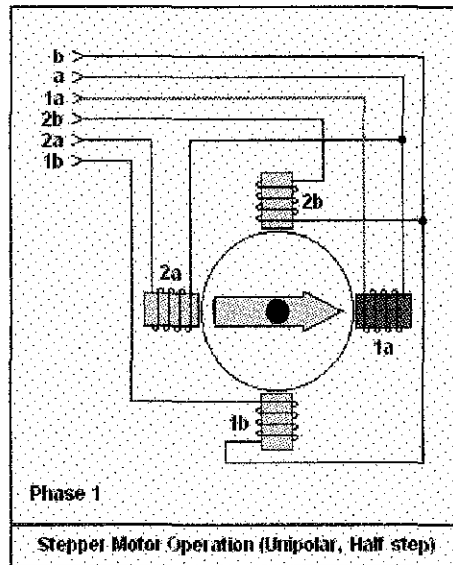


Figure 7 Stepper Motor Operation [14]

## 2.6 PIC Programmer Module

Devices called "programmers" are traditionally used to get program code into the target PIC [11]. In computer hardware, the term programmer refers to a hardware device that configures programmable non-volatile circuits such as EEPROM or programmable logic circuits. In the early days of computing, before terminal and graphical display devices, a programmer was a device used to configure a program for a computer. It usually consisted of switches and LEDs, where instructions had to be entered one by one by setting the switches in a series of "on" and "off" positions. The positions of the switches corresponded to computer instructions, similar to how assembly language is used today. Such hardware programmers are almost never seen or used today [15].

Nowadays, there are many programmers for PIC microcontrollers ranging from the extremely simple designs which rely on ICSP (In Circuit Serial Programming) to allow direct download of code from a host computer, to intelligent

programmers that can verify the device at several supply voltages. Many of these complex programmers use a pre-programmed PIC themselves to send the programming commands to the PIC that is to be programmed [11].

These are some common programmer types:

1. Simple serial port ICSP programmers
  - These generally rely on driving the PIC's Vss line negative to get the necessary voltage differences from programming. Hence they are compact and cheap but great care is needed if using them for in circuit programming [11].
2. Simple parallel port ICSP programmers
  - Simple to understand but often have much higher part counts and generally require external power supplies [11].
3. Intelligent programmers
  - Generally faster and more reliable (especially on laptops which tend to have idiosyncrasies in the way they implement their ports) but far more complex to build (in particular they tend to use a PIC in the programmer which must itself be programmed somehow) [11].

For this project, CYTRON SK40A (see Figure 8) which provided by Cytron Enterprise will be used as the PIC Programmer. SK40A have onboard voltage regulator, 7805 which will provide stable 5V output to PIC and other application. However, the maximum current of this regulator is only 1A, thus if higher current is needed, an additional voltage regulator is required. SK40A is ready with a protection diode to avoid damage to circuit if the Power Input polarity is connected wrongly. Once power is connected to Power Input, Power On LED will light up. If the LED does not light after power is connected, it might be caused by wrong polarity of power or no power from battery. SK40A also capable to accept the input voltage that range from 7V to 30V [16]. Refer to Appendix D for CYTRON SK40A circuit schematic.

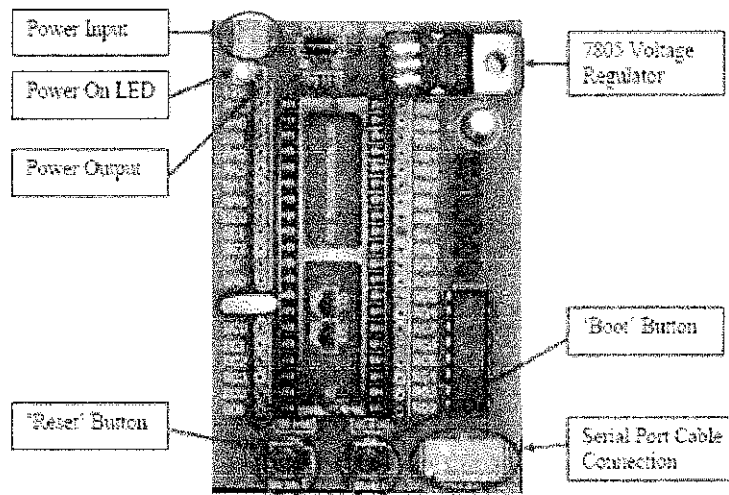


Figure 8 CYTRON SK40A PIC Programmer [16]

SK40A is also provided with bootloader capability to ease the process of loading program further save development time and cost. However, a few pin have been used for bootloader function. Pins that involved are [16]:

- MCLR, used as reset and connected to 'Reset' Button
- RB0, used as 'Boot' button and is pulled up through a 4.7K  $\Omega$  resistor to 5V
- RC7, used as Receiver Diode (Rx) and connected to MAX232
- RC6, used as Transmitter Diode (Tx) and connected to MAX232
- RD2, used a RTS and connected to MAX232
- RD3, used a CTS and connected to MAX232

## 2.7 Limit switch

Mechanical limit switches are contact sensors widely used for detecting the presence or position of objects in industrial environments. These products offer high precision in terms of accuracy and repeatability, due to the fact that physical contact is made with the target. Limit switches can be modular, with a variety of interchangeable components, or a self-contained, single-piece switch. In addition, this switch is easy to connect to microcontroller because they are either off or on, making them digital. Limit switch can be set up to turn on when the switch button is depressed and turn off when the button is released, or set it up the opposite way. It has three pin out which are Normally Close (NC), Normally Open (NO) and Common

(C). The limit switch for this project will be mounted directly on top of the power window frame and it is activated when the window glass strikes the switch to stop the motor. Figure 9 shows a typical circuit for a limit switch connection. The resistor is important because it holds the signal line at ground while the switch is off. Without it, the signal line is effectively floating because there is nothing connected to it, and may cause unreliable readings as the processor tries to decide if the line is on or off.

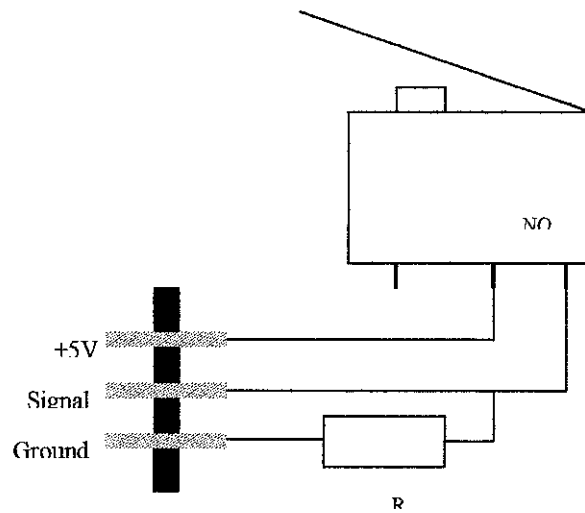


Figure 9 Limit Switch



## CHAPTER 3

### METHODOLOGY

#### 3.1 Procedure Identification

In the implementation of the project, it was divided into two phases in order to distribute the workload for the two semesters. In the first semester, activities done were literature review, research and building the initial design of all the circuits and the power window model structure. Refer to Appendix E and F for the Gantt chart and project flowchart of semester one. The second semester dealt with the circuit construction including power supply circuit, heat and rain sensor circuit and main circuit board, as well as in programming the microcontroller, rain sensor plate creation, limit switch connection and power window model structure.

The flowchart diagram for semester two is shown Figure 10. The first step of the project was to design the rain plate sensor using Eagle 3.14 and construct the actual rain plate using PCB at the laboratory. Next, designed the main circuit and heat sensor schematic using Proteus 6.14 and constructed the circuit on a donut-board. All these circuits were assembled together and connection check was done to identify the error.

The next stage was to program where the algorithm of the system was represented by using C language. The accomplished code was programmed to PIC 16F877 by using Cytron SK40A PIC programmer before the microcontroller was attached to the main circuit. The circuit was tested in order to ensure the assigned input of the microcontroller would give the correct output and the rotation of the stepper motor worked as planned. Model of power window mechanism was constructed by using perspex/acrylic and it was implemented with the programmed circuit which was constructed earlier. At this stage, the stepper motor, the rain sensor

plate and the heat sensor were mounted at the appropriate locations in order to model the prototype under the rain event and in a hot day.

Finally, trouble shooting for the system, circuit connection and physical condition were done to detect any error and at the same time to ensure the project met the objectives and the requirements. Please refer to Appendix G for detailed subprojects and keys milestone.

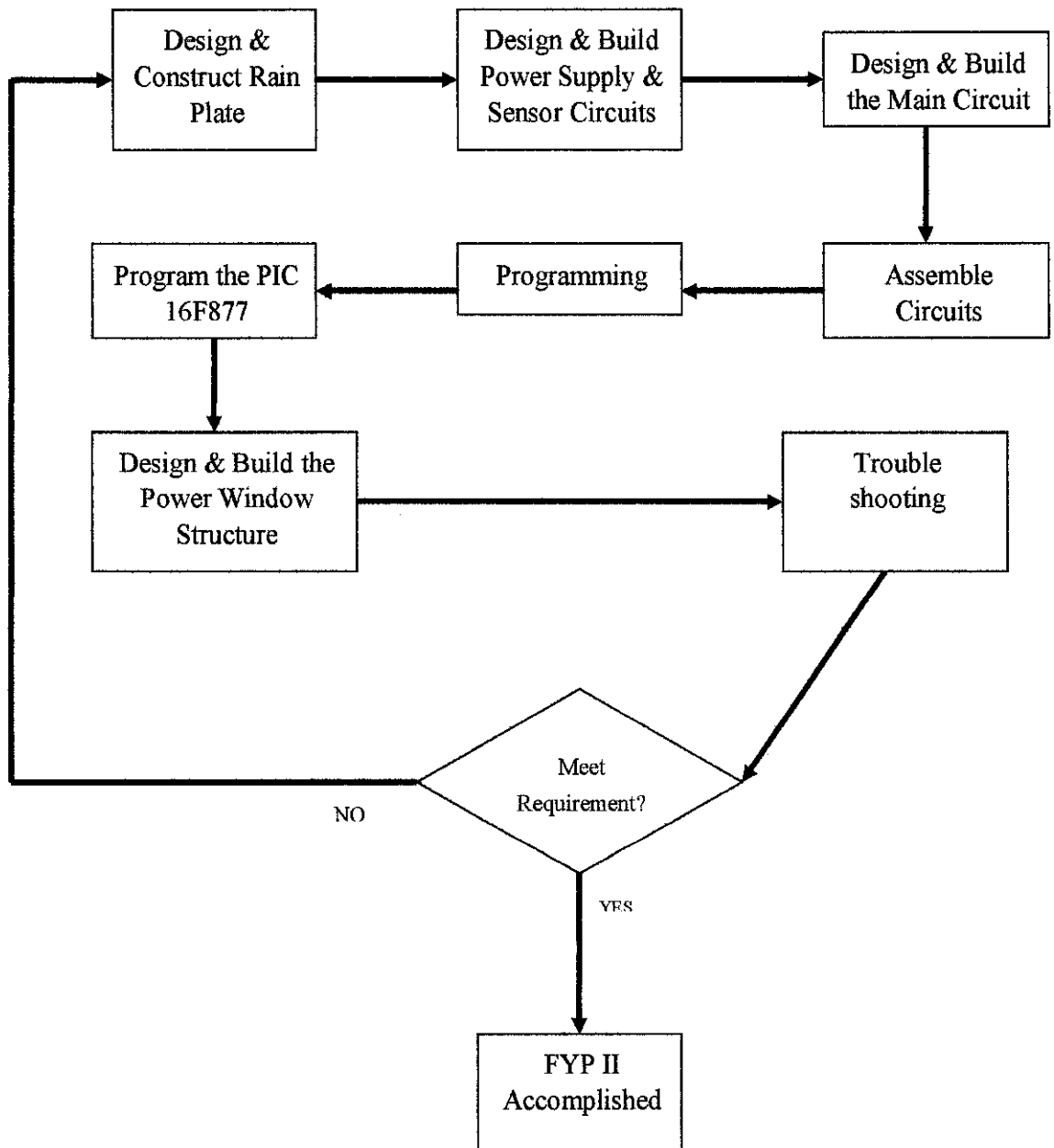


Figure 10 FYP II Work Flow

## **3.2 Tools Required**

For this project, several devices and softwares were required to be used or built.

### ***3.2.1 Hardware***

- Temperature and Rain Sensor
  - Rain sensor was made by using Printed Circuit Board (PCB) and the potential temperature sensor for this project was LM35.
- PIC Microcontroller
  - The possible PIC for this project was PIC16F877.
- Stepper Motor Driver (ULN 2803)
  - This driver was used as the final element to function like switch to control stepper motor rotation.
- Stepper Motor
  - The stepper motor was used to drive the car window up or down.

### ***3.2.2 Software***

- Proteus 6.1
  - It was used to make circuit drawing/schematic.
- Micro C & PICkit 2
  - C language was used to program the PIC microcontroller and PICki 2 to burn .hex into PIC microcontroller.
- Eagle Layout Editor
  - Schematic drawing and Gerber files creation.

### 3.3 Project Activities

#### 3.3.1 Project Architecture

This system has several modules which are power supply module, rain sensor module, temperature sensor module, limit switch, microcontroller module and stepper motor driver. Thus, these modules were done stage by stage before they were assembled together to produce the whole system. The subprojects for the heat and rain detection system for power window were summarized in the next parts. The project architecture of the subprojects is illustrated in Figure 11.

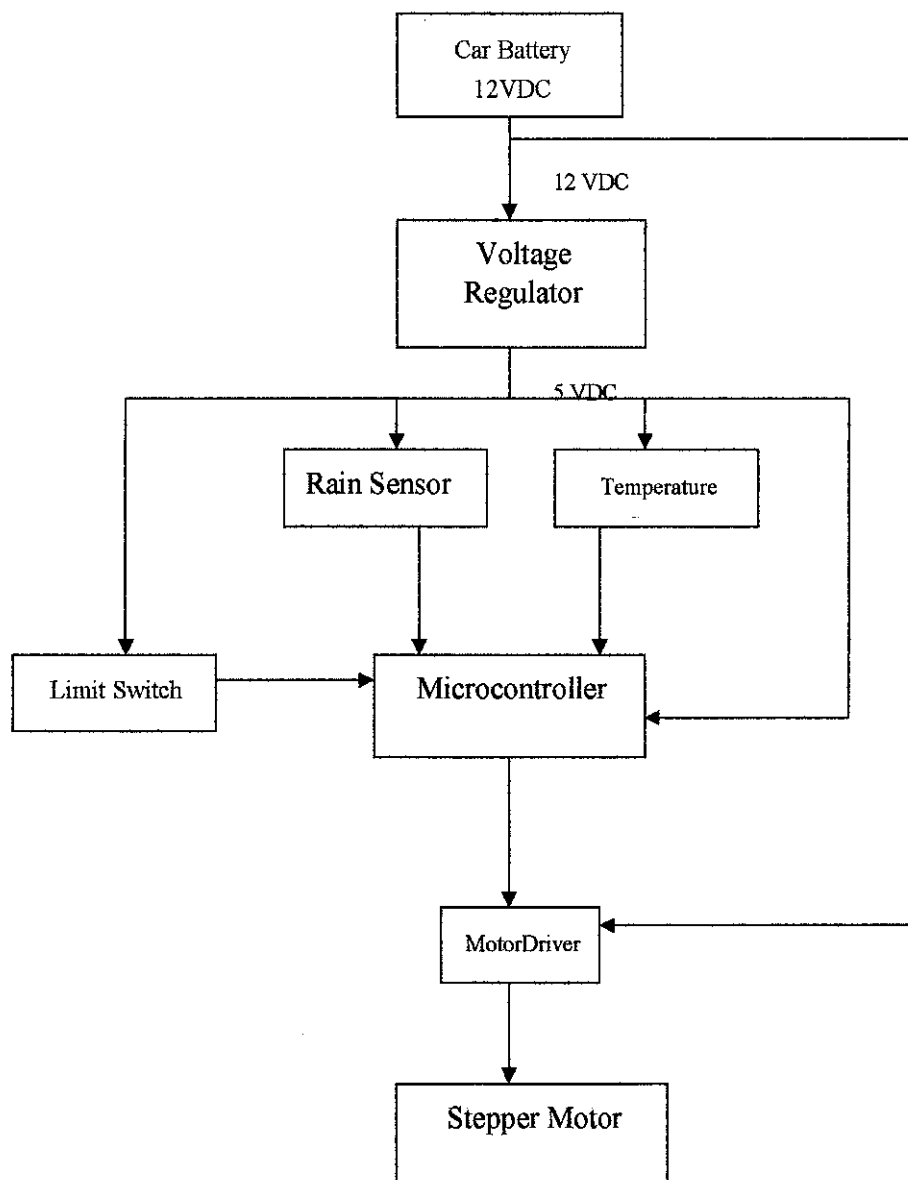


Figure 11 Architecture of the System

### 3.3.2 Rain Sensor Circuit Design

The rain sensor plate was designed and made of printed circuit board (PCB). This PCB is a copper-made board since copper is a very good conductor and widely used in electrical and electronics wire/cable industry. The rain sensor plate design was specified by using EAGLE Layout Editor before it was printed on a PCB.

It resists corrosion and is a good conductor of heat and has a high conductivity when it comes to electricity. Because of its ductility, it can be used to make wires of varying diameters, and it is very strong. Copper can also maintain solidity at 1083°C and boils at 2567°C [17]. For rain sensor design (shown in Figure 12), a resistor was placed in parallel as the drop down resistor to provide a current path to the ground so that the microcontroller could detect the input signal.

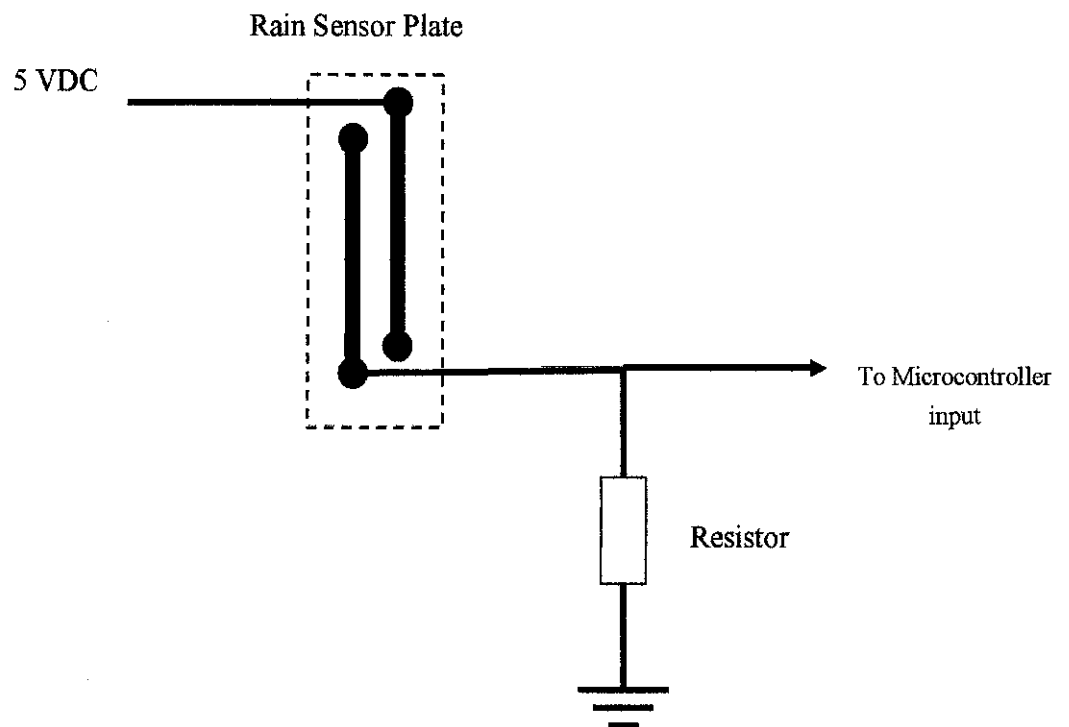


Figure 12 Rain Sensor Circuit Design

### 3.3.3 Rain Sensor Plate Design

Since the project requirement was to model a small prototype of power window mechanism, hence the size of the rain sensor plate was 2.5 cm X 4 cm (see Figure 13). The size of line spacing was 0.4 cm and it was chosen because this size was able to detect the rain drop under the minimum circumstances such as during light rain event. Therefore, the correct line spacing was appropriate when it was used under the actual rain event because response times would differ depending on whether the rain was a drizzle, a light rain, or a heavy rain.

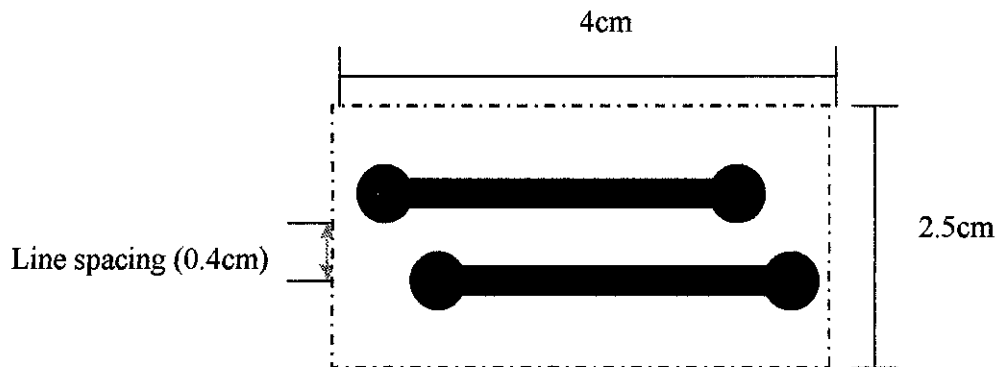


Figure 13 Rain Sensor Plate Design

### 3.3.4 Power Supply Design

Since the project used the existing 12 VDC car battery, so the voltage was stepped down to 5 VDC. This 5 VDC of voltage was required to power up microcontroller, temperature sensor, limit switch, motor driver and rain sensor. Refer to Figure 14, a voltage regulator was used in this design to drop the voltage from 12 VDC to 5 VDC. The voltage regulator used was 78L05.

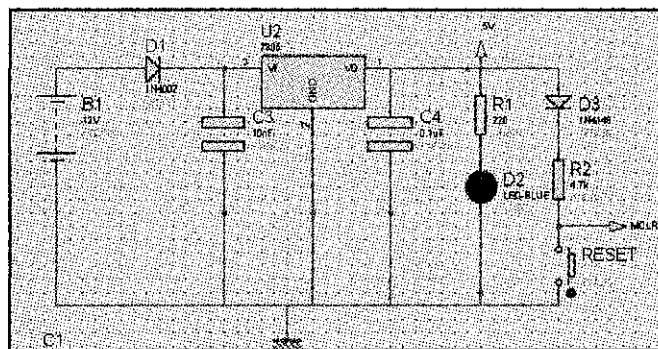


Figure 14 Power Supply Circuit Schematic

### 3.3.5 Power Supply Testing

An experiment had been conducted in order to test the power supply circuit by taking 12VDC input from the car battery and checked the output for 5 VDC. The circuit was designed to drop the voltage from 12VDC to 5VDC. A  $0.01\mu\text{F}$  and  $0.33\mu\text{F}$  capacitors were connected in parallel and acting as low pass filters as shown in Figure 15. Type of voltage regulator used in this experiment was 78L05. In the experiment, firstly the car battery voltage was measured by using a digital multimeter and the reading was 12.2 VDC (see Appendix H). After that the power supply circuit was connected to the car battery and measurement had been taken at the output terminal of the power supply circuit. The output voltage obtained was 5.0 VDC and a suitable voltage value for this project.

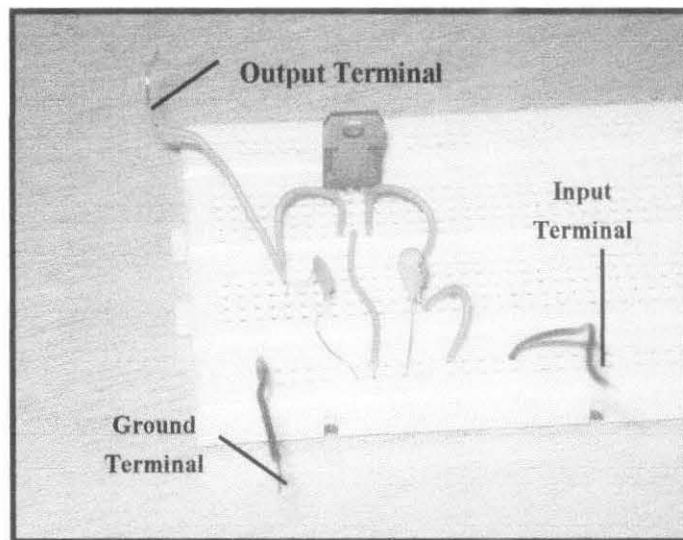


Figure 15 Power Supply Circuit

### ***3.3.6 PIC Programming***

Programming process involved 6 steps which were;

1. Analyze the Problem
2. Develop an Algorithm
3. Document the Program
4. Write Code for the Program
5. Run the Program
6. Test the Results

As stated in Structured Programming Approach Using C by Behrouz and Gilberg [18], a program is a set of step-by-step instructions that directs the computer to do the desired tasks and produce the results. A programmer must know what information will go into the software, how it will process the information, and what will be the result. All softwares must work well with three concepts as guide to be successful:

- **Input:** Information that comes from an external source and enters the software.
- **Processing:** Manages information according to a piece of software's logic. Processing is what the software does to the input it receives.
- **Output:** The information software produces after it has processed input. Output can appear on a computer screen, in a printout, or in records in a database.

The next steps were producing the pseudo code, algorithm, document the program, write the code and test the program. After that, the code produced was programmed in the PIC 16F877 before it was implemented to the whole system.

Micro C program was used to write the code in C language to control the movement of stepper motor. The program was written to receive different inputs from the temperature sensor module (LM35), rain sensor module and the limit switch. The advantage of using C language rather than using Assembly Language is that no requirement needed to program each memory allocation while in assembly language,



each memory allocation needs to be defined. For complete PIC code for Microcontroller please refer to the Appendix I. The flowchart on how to program a microcontroller is shown in Figure 16.

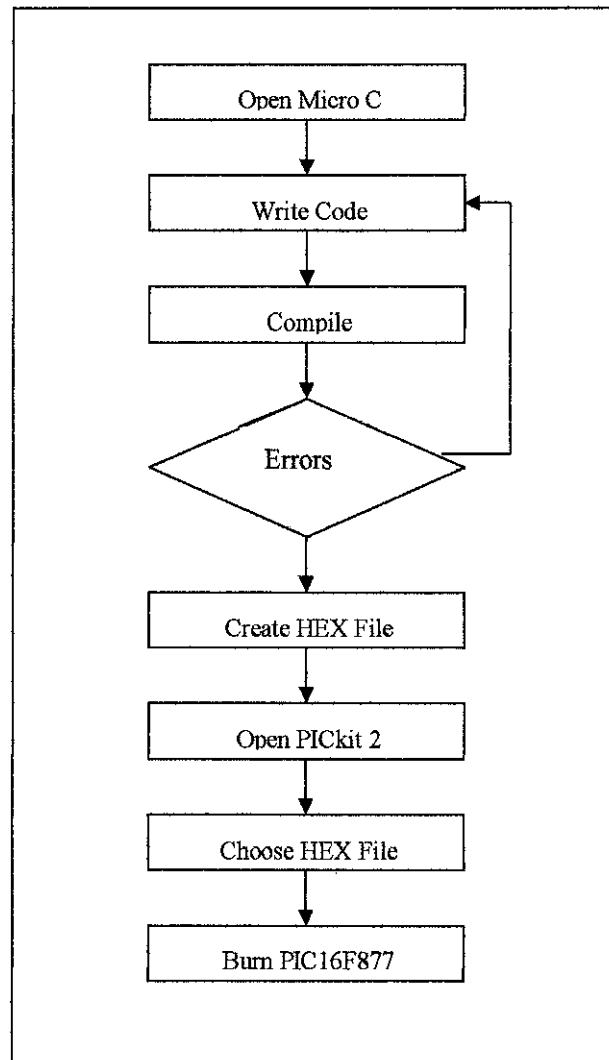


Figure 16 Flow Chart to Program the Microcontroller

On the microcontroller, A0 was set to be the input fed by temperature sensor (LM35), A1 for rain sensor plate and A3 for the limit switch. The B0-B3 on the microcontroller was connected to the stepper motor driver (ULN 2803) respectively to direct the movement of the motor rotation. These four outputs (B0-B3) each represented the connection to each stepper motor pole respectively. Please refer to

Appendix J for circuit schematic. As mentioned earlier, the stepper motor rotation was controlled by sequencing these outputs in the correct order. The output sequences for this system are elucidated in Table 2 below.

Table 2 Microcontroller Operating Algorithm

Event	Microcontroller							Actions
	Input			Output				
	A0	A1	A2	B3	B2	B1	B0	
Hot Day	1	0	0	1	0	0	0	Open the Window for one inch
				0	1	0	0	
Rain	0	1	0	0	0	0	1	Close the Window
				0	0	1	0	
				0	1	0	0	
				1	0	0	0	
Limit switch activated	0	0	1	0	0	0	0	Stop the Motor Rotation

### 3.3.7 Creation of Gerber files

A Gerber File is a standard file format used by printed circuit board (PCB) fabrication houses that contains information necessary for computer controlled machines to draw exact patterns for circuit boards. The software, EAGLE 4.13, was used to create schematics and Gerber files. When making an actual printed circuit board based on data made from Computer Aided Design (CAD), the data of Gerber form are used in many cases. Gerber data are the data formats which a photograph plotter maker's Gerber Scientific Instrument Company created. All the information



The LM35 - An Integrated Circuit Temperature Sensor (see Figure 20) was connected to a capacitor as shown in Figure 19. The voltage source was supplied from the output of power supply which is 5VDC and it was connected to the leg 1, the leg 2 to the ground and leg 3 to the input microcontroller (A0). The capacitor was connected between leg 2 and leg 3. The sensor has a sensitivity of 10 mV/ °C or 100 °C/V, and since the LM35 is an integrated circuit sensor that is used to measure temperature with an electrical output proportional to the temperature (in °C), so the general equation used to convert output voltage to temperature is:

$$\text{Temperature ( } ^\circ\text{C)} = \text{Vout} \times (100 \text{ } ^\circ\text{C/V})$$

### ***3.3.9 Power Window Model Structure***

This section models the prototype of power window that would be interfaced with the heat and rain detection system. A model prototype had been designed and developed in order to show how the system works. Based on Figure 21, the rain plate which was the part that detected rain water drops was mounted on the top of the structure. Water presence gave logic 1 to microcontroller to trigger the motor to close the power window if the window was not fully closed.

The limit switch was mounted on the left top of the frame because when the window struck it, the motor rotation would stop immediately. Power window lifting mechanism was constructed by using perspex/acrylic and a gear with the linkage was engaged to the stepper motor teeth. The linkage has a long arm, which was attached to a bar that holds the bottom of the window. The end of the arm could slide in a groove in the bar as the window rises. On the other end of the bar is a large plate that has gear teeth cut into it where the motor turned a gear that engaged to these teeth.

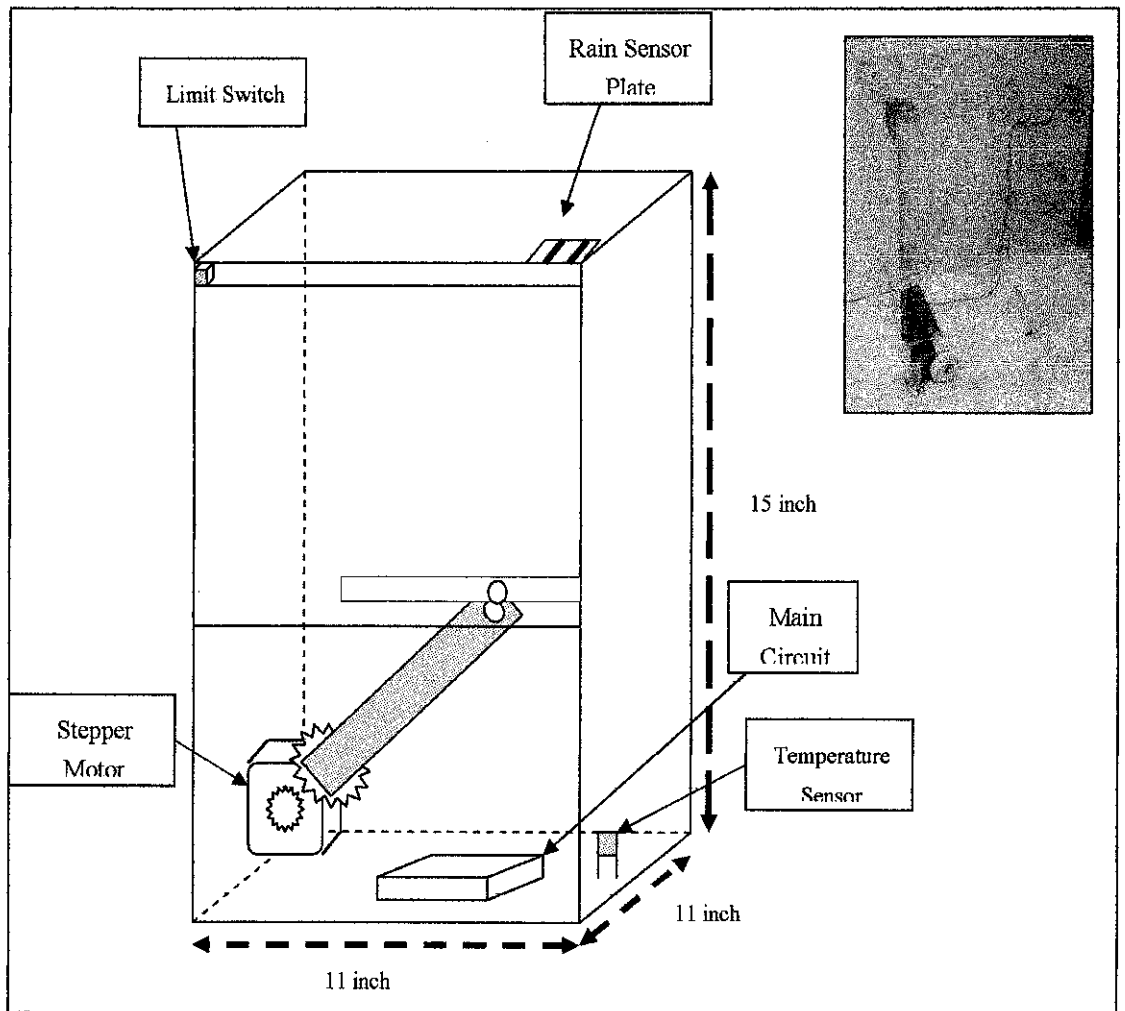


Figure 21 Power Window Model Structure

### 3.3.10 Motor Driver Sequence

In a stepper motor, speed and power are controlled separately. The current that is provided to the windings control the torque or the force that the motor applies to turn or to hold its position. The rotation speed is determined by the rate at which current will be moved from one winding to the next. On the other hand, the speed is independent of the torque. So, to control stepper motor, an appropriate driver was needed and in this project, ULN2803 driver was used (refer Figure 22).

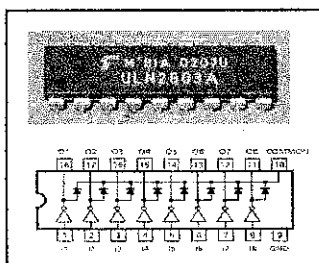


Figure 22 ULN 2803

The input to the ULN2803 was directly from an I/O port of the PIC16F877 microcontroller (B0-B3). Four output lines from ULN2803 were used by one stepper motor and in this project, the requirements were to control the motor rotating in clockwise and counter wise clock direction. The output sequence of microcontroller was very important in determining the direction of the motor rotation. Thus, the motor might be turned by successively outputting the following patterns to the motor windings in sequence as shown in Table 3.

Table 3 Moving the Motor Clockwise

d7	d6	d5	d4	d3	d2	d1	d0	HEX
0	0	0	0	0	0	0	1	1H
0	0	0	0	0	0	1	0	2H
0	0	0	0	0	1	0	0	4H
0	0	0	0	1	0	0	0	8H
0	0	0	0	0	0	0	1	1H
0	0	0	0	0	0	1	0	2H
0	0	0	0	0	1	0	0	4H
0	0	0	0	1	0	0	0	8H

Looking at Table 3, the project only used d0 (which was also pin 2) to d3 (which was also pin 5) to move the motor clockwise. The shaded part is always 0 or a low signal because they are unused. On the right of Table 3 is the hexadecimal equivalent of the binary value that will be sent out to the parallel port. So if the motor were moving clockwise (assuming clockwise starts from d0 to d3 from Table 3) it would use values in the range from 1 to 8 in decimal. If stepper motor was moving counter clockwise, it would start from 8 down to 1 and back to 8 again. Please refer Appendix K for ULN2803 datasheet.

## CHAPTER 4

### RESULTS AND DISCUSSION

#### 4.1 Data Gathering and Analysis

##### 4.1.1 Experiment 1

Some general temperature readings were made and used as guide in this project. By using a thermometer, the temperatures were measured for every 30 minutes interval inside the car between 12.15 p.m. to 2.15 p.m. The results obtained are shown in Table 4

Table 4 Temperature Readings in a Hot Day

NO	TIME	Temperature (°C)
1	12.15 p.m.	39
2	12.45 p.m.	41
3	1.15 p.m.	40
4	1.45 p.m.	42
5	2.15 p.m.	39

$$\begin{aligned}\text{Average temperature} &= (39^{\circ}\text{C} + 41^{\circ}\text{C} + 40^{\circ}\text{C} + 42^{\circ}\text{C} + 39^{\circ}\text{C}) / 5 \\ &= 40.2^{\circ}\text{C}\end{aligned}$$

Based on the results above, the average temperature was relatively high. This level of temperature is capable to damage the internal rubber-made accessories if the car is left for a long period of time in a hot day.

#### 4.1.2 Experiment 2

Another experiment had been conducted in order to know the average temperature in a hot day and it was done for three days. The second objective was to know the average temperature drop when the car windows were open for one inch for 10 minutes. This experiment was conducted between 12.15 p.m. to 2.15 p.m. and 5 temperature readings were taken for every 30 minutes interval. The results are shown in Table 5 and Table 6. A thermometer was left inside the car between 12.00 p.m. to 2.15 p.m. and the temperature would be taken for every 30 minutes interval. After taking each reading, the car windows were opened for one inch in order to let the hot air flow outside. After 10 minutes, the temperature inside the car was measured again in order to observe whether the temperature would drop or not.

Table 5 Temperature Readings in a Hot Day (Car Window Close).

NO	TIME	DAY 1	DAY 2	DAY 3
		Temperature (°C)	Temperature (°C)	Temperature (°C)
1	12.15 p.m.	46	44	46
2	12.45 p.m.	45	44	46
3	1.15 p.m.	47	45	46
4	1.45 p.m.	47	47	47
5	2.15 p.m.	46	47	46
TOTAL		231	227	231

Therefore, the average temperature inside a closed window car (Proton Wira) between 12.15 p.m. to 2.15 p.m. for Day 1, Day 2 and Day 3 was,

$$= (231\text{ }^{\circ}\text{C} + 227\text{ }^{\circ}\text{C} + 231\text{ }^{\circ}\text{C}) / 15 = 45.9\text{ }^{\circ}\text{C}$$



Table 6 Temperature Readings in a Hot Day (Car Window Open)

NO	TIME	DAY 1	DAY 2	DAY 3
		Temperature (°C)	Temperature (°C)	Temperature (°C)
1	12.25 p.m.	45	43	45
2	12.55 p.m.	44	43	45
3	1.25 p.m.	45	43	44
4	1.55 p.m.	46	46	45
5	2.25 p.m.	44	46	44
TOTAL		224	221	223

Therefore, the average temperature inside the same car (Proton Wira) after car window was opened for 10 minutes between 12.15 p.m. to 2.15 p.m. for Day 1, Day 2 and Day 3 was,

$$(224\text{ }^{\circ}\text{C} + 221\text{ }^{\circ}\text{C} + 223\text{ }^{\circ}\text{C}) / 15 = 44.5\text{ }^{\circ}\text{C}$$

From Table 5 and Table 6, the average temperature drop after car window was opened for one inch in 10 minutes was,

$$(45.9\text{ }^{\circ}\text{C} - 44.5\text{ }^{\circ}\text{C}) = 1.4\text{ }^{\circ}\text{C}.$$

### **4.1.3 Experiment 3**

Since the temperature inside the car might be different between the front seat and the back seat, an experiment had been conducted in order to calculate the average temperature inside car under three conditions. The experiment was conducted for two days so that the average temperature would be more accurate.

- Condition 1: between 8 a.m. – 9 a.m.
- Condition 2: between 12 p.m. – 2 p.m.
- Condition 3: between 12 p.m. – 2 p.m. (under a shade).

One thermometer had been placed between front seats and another thermometer at the back seat inside the car. The readings for both thermometers were taken at the same time.

Condition 1: between 8 a.m. – 9 a.m.

A car (Proton Wira) was parked in an open area and left between 8 a.m. to 9 a.m. One thermometer was placed between front seats and another thermometer at the back seat. The readings were taken for every 15 minutes interval. Refer to Table 7 for temperature readings obtained.

Table 7 Temperature Readings (8 a.m. – 9 a.m.)

NO	TIME	DAY 1		DAY 2	
		Temperature (°C) (front seat)	Temperature (°C) (back seat)	Temperature (°C) (front seat)	Temperature (°C) (back seat)
1	8.00 a.m.	28	28	26	26
2	8.15 a.m.	28	28	27	27
3	8.30 a.m.	29	29	28	28
4	8.45 a.m.	29	29	29	28
5	9.00 a.m.	29	29	29	29
TOTAL		143	143	139	138

Average temperature from front seat =  $(143 + 139) / 10 = 28.2 \text{ }^{\circ}\text{C}$

Average temperature from back seat =  $(143 + 138) / 10 = 28.1 \text{ }^{\circ}\text{C}$

Therefore, the average temperature in the car under condition 1

$$= (28.2 \text{ }^{\circ}\text{C} + 28.1 \text{ }^{\circ}\text{C})/2$$

$$= 28.15 \text{ }^{\circ}\text{C}$$

Condition 2: between 12.00 p.m. – 2.00 p.m.

A car was parked in an open area and exposed to sunlight between 12 p.m. to 2 p.m. All car windows were completely closed and the thermometers were placed at the front seat and at the back seat respectively. The readings were taken in 30 minutes interval. Refer to Table 8 for the temperature readings obtained.

Table 8 Temperature Readings ( 12 p.m. – 2.00 p.m.)

NO	TIME	DAY 1		DAY 2	
		Temperature (°C) (front seat)	Temperature (°C) (back seat)	Temperature (°C) (front seat)	Temperature (°C) (back seat)
1	12.00 p.m.	45	45	45	45
2	12.30 p.m.	45	45	46	46
3	1.00 p.m.	47	46	46	46
4	1.30 p.m.	47	47	47	46
5	2.00 p.m.	47	47	47	47
TOTAL		231	230	231	230

Average temperature from front seat =  $( 231 + 231 ) / 10 = 46.2 \text{ }^{\circ}\text{C}$

Average temperature from back seat =  $( 230 + 230 ) / 10 = 46.0 \text{ }^{\circ}\text{C}$

Therefore, the average temperature in the car under condition 2

$$= ( 46.2 \text{ }^{\circ}\text{C} + 46.0 \text{ }^{\circ}\text{C} ) / 2$$

$$= 46.1 \text{ }^{\circ}\text{C}$$

Condition 3: between 12.00 p.m. – 2.00 p.m. ( under a shade)

Another car (Proton Wira ) was parked under a shade between 12 p.m. and 2 p.m. at the same time the temperature readings for condition 2 were being measured. All car windows were completely close and the thermometers were placed at the front seat and at the back seat respectively. The readings were taken in 30 minutes interval. Refer to Table 9 for the temperature readings obtained.

Table 9 Temperature Readings, under a shade ( 12 p.m. – 2.00 p.m.)

NO	TIME	DAY 1		DAY 2	
		Temperature (°C) (front seat)	Temperature (°C) (back seat)	Temperature (°C) (front seat)	Temperature (°C) (back seat)
1	12.00 p.m.	34	34	35	35
2	12.30 p.m.	34	33	34	34
3	1.00 p.m.	34	33	34	34
4	1.30 p.m.	34	33	34	34
5	2.00 p.m.	33	33	34	33
TOTAL		169	166	171	170

Average temperature for front seat =  $( 169 + 171 ) / 10 = 34.0 \text{ } ^\circ\text{C}$

Average temperature for back seat =  $( 166 + 170 ) / 10 = 33.6 \text{ } ^\circ\text{C}$

Therefore, the average temperature in the car under condition 3

$$= ( 34.0 \text{ } ^\circ\text{C} + 33.6 \text{ } ^\circ\text{C} ) / 2$$

$$= 33.8 \text{ } ^\circ\text{C}$$

From the results of the experiment conducted, the excessive temperature could be decided by calculating the average temperature from results of conditions.

Average temperature condition 1 + average temperature condition 2 + average temperature condition 3

$$= ( 28.15^\circ\text{C} + 46.1 \text{ } ^\circ\text{C} + 33.8 \text{ } ^\circ\text{C} ) / 3 = 36.02 \text{ } ^\circ\text{C}$$

Therefore, 36.0 °C was considered and chosen as excessive temperature to trigger the power window motor to open the car window for one inch. Based on the results also, the placement of the heat sensor would be at the front seat since the temperature was slightly higher than the temperature at the back seat.

## 4.2 Threshold Output Voltage Calculation

From the results of experiments conducted before, the threshold temperature to trigger the power window to be opened for one inch was set to 36 °C. Hence, the threshold output voltage of LM35 could be calculated since the electrical output is proportional to the temperature (in °C) ( Refer to Figure 23). This value of threshold output voltage was set in the microcontroller to give the output to let the window be opened for one inch.

$$\text{Temperature}(\text{°C}) = V_{out} \times (100\text{°C/V})$$

$$\begin{aligned} \therefore V_{out} &= \frac{\text{Temperature}(\text{°C})}{(100\text{°C/V})} \\ &= \frac{36\text{°C}}{100\text{°C/V}} \\ &= 0.36\text{V} \end{aligned}$$

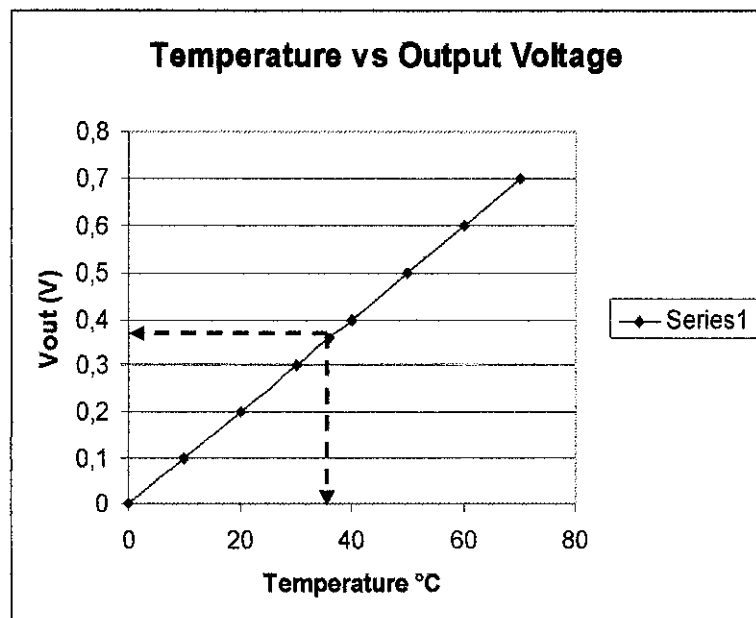


Figure 23 Temperature (°C) Vs Vout(V)

## **CHAPTER 5**

### **CONCLUSION AND RECOMMENDATIONS**

#### **5.1 Conclusion**

In this project, the author has designed a prototype to establish an idea of power window system development in a vehicle. The project used sensor and microcontroller, and these components were found to be very sensitive. The driver of the stepper motor overheated when the system was activated and made the motor rotation unstable. To solve this problem, resistance needs to be added to the output of the microcontroller to decrease and stabilize the output current. When this system is applied to the actual power window mechanism in vehicle, the system will prevent internal car accessory from damage when the car is parked in a hot day or in a raining day. In addition, it will also give convenience to the driver and at the same time give some values to the automobile industry. This project will be a very useful product for local market since the benefits it offers are very significant and related with weather in Malaysia.

#### **5.2 Recommendations**

In terms of security, alarm and movement sensor such as infra red sensor can be applied to make the system more secured especially when the power window is automatically opened for once inch. Besides that, to increase the rate of releasing hot air to the outside, ventilation fan can be installed in order to decrease the temperature faster. Another consideration is that there is a potential safety hazard when the rain detection system drives the window up. This is because the system does not take into account whether or not somebody or something is in the path of the window when powering the motors. Thus, this is another future improvement and would possibly require the use of pressure sensors that would be mounted in the power window system.

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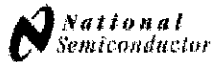
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## **APPENDICES**

# APPENDIX A

## LM78LXX DATASHEET



April 2006

### LM78LXX Series 3-Terminal Positive Regulators

#### General Description

The LM78LXX series of three terminal positive regulators is available with several fixed output voltages making them useful in a wide range of applications. When used as a zener diode/resistor combination replacement, the LM78LXX usually results in an effective output impedance improvement of two orders of magnitude, and lower quiescent current. These regulators can provide local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow the LM78LXX to be used in logic systems, instrumentation, HIFI, and other solid state electronic equipment.

The LM78LXX is available in the plastic TO-92 (Z) package, the plastic SO-8 (M) package and a chip sized package (8-Bump micro SMD) using National's micro SMD package technology. With adequate heat sinking the regulator can deliver 100mA output current. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistors is provided to limit inter-

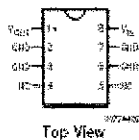
nal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

#### Features

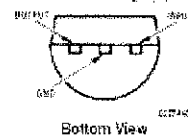
- LM78L06 in micro SMD package
- Output voltage tolerances of  $\pm 5\%$  over the temperature range
- Output current of 100mA
- Internal thermal overload protection
- Output transistor safe area protection
- Internal short circuit current limit
- Available in plastic TO-92 and plastic SO-8 low profile packages
- No external components
- Output voltages of 5.0V, 6.2V, 8.2V, 9.0V, 12V, 15V
- See AN-1112 for micro SMD considerations

#### Connection Diagrams

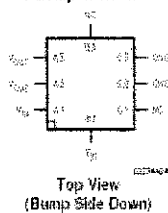
SO-8 Plastic (M)  
(Narrow Body)



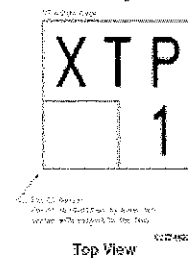
(TO-92)  
Plastic Package (Z)



8-Bump micro SMD



micro SMD Marking Orientation



**Absolute Maximum Ratings** (Note 1)

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

Power Dissipation (Note 5)	Internally Limited
Input Voltage	35V
Storage Temperature	-65°C to +150°C
ESD Susceptibility (Note 2)	1kV

Operating Junction Temperature

SO-8, TO-92	0°C to 125°C
micro SMD	-40°C to 85°C

Soldering Information

Ironed or Convection (20 sec.)	235°C
Wave Soldering (10 sec.)	220°C (lead time)

**LM78LXX Electrical Characteristics** Limits in standard typeface are for  $T_J = 25^\circ\text{C}$ . Bold typeface applies over  $0^\circ\text{C}$  to  $125^\circ\text{C}$  for SO-8 and TO-92 packages, and  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  for micro SMD package. Limits are guaranteed by production testing or correlation techniques using standard Statistical Quality Control (SQC) methods. Unless otherwise specified:  $I_O = 40\text{mA}$ ,  $C_1 = 0.33\mu\text{F}$ ,  $C_2 = 0.1\mu\text{F}$ .

**LM78L05**

Unless otherwise specified,  $V_{IN} = 10\text{V}$

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_O$	Output Voltage		4.8	5	5.2	V
		$7\text{V} \leq V_{IN} \leq 20\text{V}$ $1\text{mA} \leq I_O \leq 40\text{mA}$ (Note 3)	4.75		5.25	
		$1\text{mA} \leq I_O \leq 70\text{mA}$ (Note 3)	4.75		5.25	
$\Delta V_O$	Line Regulation	$7\text{V} \leq V_{IN} \leq 20\text{V}$		18	75	mV
		$8\text{V} \leq V_{IN} \leq 20\text{V}$		10	54	
$\Delta V_O$	Load Regulation	$1\text{mA} \leq I_O \leq 100\text{mA}$		20	60	mV
		$1\text{mA} \leq I_O \leq 40\text{mA}$		5	30	
$I_Q$	Quiescent Current			3	5	mA
$\Delta I_Q$	Quiescent Current Change	$8\text{V} \leq V_{IN} \leq 20\text{V}$			1.0	mA
		$1\text{mA} \leq I_O \leq 40\text{mA}$			0.1	
$V_n$	Output Noise Voltage	$f = 10\text{ Hz to } 100\text{ kHz}$ (Note 4)		40		$\mu\text{V}$
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	$f = 120\text{ Hz}$ $8\text{V} \leq V_{IN} \leq 16\text{V}$	47	62		dB
$I_{PK}$	Peak Output Current			140		mA
$\frac{\Delta V_O}{\Delta T}$	Average Output Voltage Tempco	$I_O = 5\text{mA}$		-0.65		mV/°C
$V_{IN}(\text{Min})$	Minimum Value of Input Voltage Required to Maintain Line Regulation			6.7	7	V
$\theta_{JA}$	Thermal Resistance (8-Bump micro SMD)			290.8		°C/W

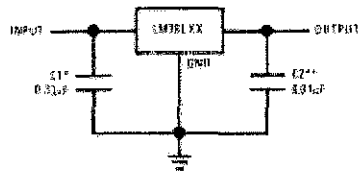
**LM78L62AC**

Unless otherwise specified,  $V_{IN} = 12\text{V}$

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$V_O$	Output Voltage		5.95	6.2	6.45	V
		$8.5\text{V} \leq V_{IN} \leq 20\text{V}$ $1\text{mA} \leq I_O \leq 40\text{mA}$ (Note 3)	5.9		6.5	
		$1\text{mA} \leq I_O \leq 70\text{mA}$ (Note 3)	5.9		6.5	

## Typical Applications

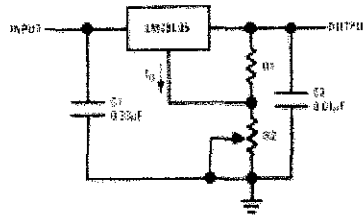
### Fixed Output Regulator



007149

\*Required if the regulator is located more than 5" from the power supply filter.  
 \*\*See (Note 4) in the electrical characteristics table.

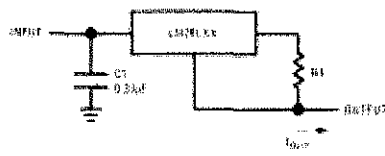
### Adjustable Output Regulator



007148

$V_{OUT} = 5V + (5V/R1) \cdot I_Q \cdot R2$   
 $5V/R1 \geq 3 I_Q$ , load regulation ( $I_Q$ ) =  $(R1 + R2)/R1$  ( $I_Q$  of LM317L5)

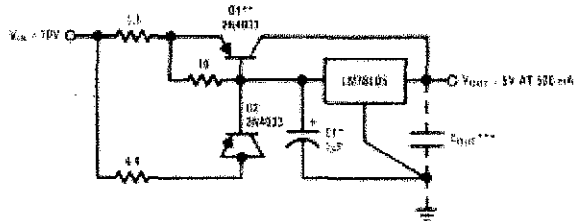
### Current Regulator



007147

$I_{OUT} = (V_{OUT}/R1) - I_Q$   
 $I_Q = 1.5mA$  over line and load changes

### 5V, 500mA Regulator with Short Circuit Protection

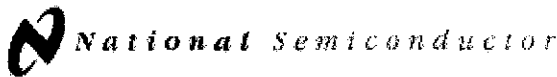


007145

\*Solid tantalum.  
 \*\*Heat sink 0.1.  
 \*\*\*Optional: improves ripple rejection and transient response.  
 Load Regulation: 0.8% @  $I_Q \leq 250mA$  pulsed with  $I_{OUT} = 500mA$ .

# APPENDIX B

## LM 35 DATASHEET



December 1984

### LM35/LM35A/LM35C/LM35CA/LM35D 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  $\pm 1/4^\circ\text{C}$  at room temperature and  $\pm 3/4^\circ\text{C}$  over a full  $-55$  to  $+150^\circ\text{C}$  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  $\mu\text{A}$  from its supply, it has very low self-heating, less than  $0.1^\circ\text{C}$  in still air. The LM35 is rated to operate over a  $-55$  to  $+150^\circ\text{C}$  temperature range, while the LM35C is rated for a  $-40$  to  $+110^\circ\text{C}$  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-202 package.

#### Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear  $+10.0\text{ mV}/^\circ\text{C}$  scale factor
- $0.5^\circ\text{C}$  accuracy guaranteeable (at  $+25^\circ\text{C}$ )
- Rated for full  $-55$  to  $+150^\circ\text{C}$  range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60  $\mu\text{A}$  current drain
- Low self-heating,  $0.08^\circ\text{C}$  in still air
- Nonlinearity only  $\pm 1/4^\circ\text{C}$  typical
- Low impedance output,  $0.1\ \Omega$  for 1 mA load

#### Connection Diagrams

TO-46  
Metal Can Package\*



TL9615516-1

\*GND is connected to negative pin (GND)

Order Number LM35H, LM35AH,  
LM35CH, LM35CAH or LM35DH  
See NS Package Number HD3H

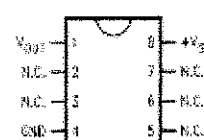
TO-92  
Plastic Package



TL9615516-2

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

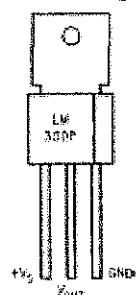
SO-8  
Small Outline Molded Package



TL9615516-3

Top View  
N.C. = No Connection  
Order Number LM35DM  
See NS Package Number M08A

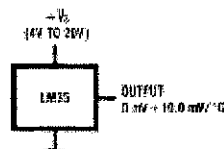
TO-202  
Plastic Package



TL9615516-4

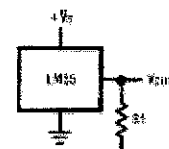
Order Number LM35DP  
See NS Package Number P03A

#### Typical Applications



TL9615516-5

FIGURE 1. Basic Centigrade  
Temperature  
Sensor ( $-2^\circ\text{C}$  to  $+150^\circ\text{C}$ )



TL9615516-4

Choose  $R_L = -V_{out}/60\ \mu\text{A}$

$V_{out} = +1.500\text{ mV}$  at  $+150^\circ\text{C}$   
 $= +250\text{ mV}$  at  $+25^\circ\text{C}$   
 $= -550\text{ mV}$  at  $-55^\circ\text{C}$

FIGURE 2. Full-Range Centigrade  
Temperature Sensor

THE SEMTEC is a registered trademark of National Semiconductor Corporation.

### 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	+5V to -1.0V
Output Current	10 mA
Storage Temp., TO-46 Package,	-60°C to +160°C
TO-92 Package,	-50°C to +150°C
SO-8 Package,	-65°C to +150°C
TO-202 Package,	-65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 Package, (Soldering, 10 seconds)	260°C
TO-202 Package, (Soldering, 10 seconds)	+230°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 (Note 1) (Note 5)

Parameter	Conditions	LM35A			LM35CA			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy (Note 7)	$T_A = +25^\circ\text{C}$	$\pm 0.2$	$\pm 0.5$		$\pm 0.2$	$\pm 0.5$	$\pm 1.0$	$^\circ\text{C}$
	$T_A = -10^\circ\text{C}$	$\pm 0.3$			$\pm 0.3$		$\pm 1.0$	$^\circ\text{C}$
	$T_A = T_{MAX}$	$\pm 0.4$	$\pm 1.0$		$\pm 0.4$	$\pm 1.0$	$\pm 1.5$	$^\circ\text{C}$
	$T_A = T_{MIN}$	$\pm 0.4$	$\pm 1.0$		$\pm 0.4$	$\pm 1.0$	$\pm 1.5$	$^\circ\text{C}$
Nonlinearity (Note 8)	$T_{MIN} \leq T_A \leq T_{MAX}$	$\pm 0.15$		$\pm 0.35$	$\pm 0.15$		$\pm 0.3$	$^\circ\text{C}$
Sensor Gain (Average Slope)	$T_{MIN} \leq T_A \leq T_{MAX}$	+10.0	+9.9, +10.1		+10.0		+9.9, +10.1	mV/ $^\circ\text{C}$
Load Regulation (Note 3) $0 \leq I_L \leq 1 \text{ mA}$	$T_A = +25^\circ\text{C}$ $T_{MIN} \leq T_A \leq T_{MAX}$	$\pm 0.4$ $\pm 0.5$	$\pm 1.0$	$\pm 3.0$	$\pm 0.4$ $\pm 0.5$	$\pm 1.0$	$\pm 3.0$	mV/mA mV/mA
Line Regulation (Note 3)	$T_A = +25^\circ\text{C}$ $4V \leq V_S \leq 30V$	$\pm 0.01$ $\pm 0.02$	$\pm 0.05$	$\pm 0.1$	$\pm 0.01$ $\pm 0.02$	$\pm 0.05$	$\pm 0.1$	mV/V mV/V
Quiescent Current (Note 2)	$V_S = +5V, +25^\circ\text{C}$	56	57		56	57	114	$\mu\text{A}$
	$V_S = +5V$	105		131	91		114	$\mu\text{A}$
	$V_S = +30V, +25^\circ\text{C}$	56.2	58		56.2	58	116	$\mu\text{A}$
	$V_S = +30V$	105.5		133	91.5		116	$\mu\text{A}$
Change of Quiescent Current (Note 3)	$4V \leq V_S \leq 30V, +25^\circ\text{C}$	0.2	1.0		0.2	1.0	2.0	$\mu\text{A}$
	$4V \leq V_S \leq 30V$	0.5		2.0	0.5		2.0	$\mu\text{A}$
Temperature Coefficient of Quiescent Current		+0.39		+0.5	+0.39		+0.5	$\mu\text{A}/^\circ\text{C}$
Minimum Temperature for Rated Accuracy	In circuit of Figure 1, $I_L = 0$	+1.5		+2.0	+1.5		+2.0	$^\circ\text{C}$
Long Term Stability	$T_A = T_{MAX}$ , for 1000 hours	$\pm 0.05$			$\pm 0.05$			$^\circ\text{C}$

Note 1: Unless otherwise noted, these specifications apply:  $-55^\circ\text{C} \leq T_{J,C} \leq +100^\circ\text{C}$  for the LM35 and LM35A;  $-40^\circ\text{C} \leq T_{J,C} \leq +110^\circ\text{C}$  for the LM35C and LM35CA; and  $0^\circ\text{C} \leq T_{J,C} \leq +100^\circ\text{C}$  for the LM35D.  $V_S = +5V$  and  $I_{LOAD} = 50 \mu\text{A}$  in the circuit of Figure 2. These specifications also apply from  $+2^\circ\text{C}$  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  $400^\circ\text{C}/\text{W}$  junction to ambient, and  $24^\circ\text{C}/\text{W}$  junction to case. Thermal resistance of the TO-92 package is  $150^\circ\text{C}/\text{W}$  junction to ambient. Thermal resistance of the small outline molded package is  $220^\circ\text{C}/\text{W}$  junction to ambient. Thermal resistance of the TO-202 package is  $80^\circ\text{C}/\text{W}$  junction to ambient. For additional thermal resistance information see table in the Applications section.

### Electrical Characteristics (Note 1) (Note 6) (Continued)

Parameter	Conditions	LM35			LM35C, LM35D			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy, LM35, LM35C (Note 7)	$T_A = +25^\circ\text{C}$	$\pm 0.4$	$\pm 1.0$		$\pm 0.4$	$\pm 1.0$	$^\circ\text{C}$	
	$T_A = -10^\circ\text{C}$	$\pm 0.5$			$\pm 0.5$	$\pm 1.5$	$^\circ\text{C}$	
	$T_A = T_{\text{MAX}}$	$\pm 0.8$	$\pm 1.5$		$\pm 0.8$	$\pm 1.5$	$^\circ\text{C}$	
	$T_A = T_{\text{MIN}}$	$\pm 0.8$		$\pm 1.5$	$\pm 0.8$	$\pm 2.0$	$^\circ\text{C}$	
Accuracy, LM35D (Note 7)	$T_A = +25^\circ\text{C}$				$\pm 0.8$	$\pm 1.5$	$^\circ\text{C}$	
	$T_A = T_{\text{MAX}}$				$\pm 0.9$	$\pm 2.0$	$^\circ\text{C}$	
	$T_A = T_{\text{MIN}}$				$\pm 0.9$	$\pm 2.0$	$^\circ\text{C}$	
Nonlinearity (Note 8)	$T_{\text{MIN}} < T_A < T_{\text{MAX}}$	$\pm 0.3$		$\pm 0.5$	$\pm 0.2$	$\pm 0.5$	$^\circ\text{C}$	
Sensor Gain (Average Slope)	$T_{\text{MIN}} < T_A < T_{\text{MAX}}$	$+ 10.0$	$+ 9.8,$ $+ 10.2$		$+ 10.0$	$+ 9.8,$ $+ 10.2$	mV/ $^\circ\text{C}$	
Load Regulation (Note 3) $I_{\text{OCL}} \leq 1 \text{ mA}$	$T_A = +25^\circ\text{C}$	$\pm 0.4$	$\pm 2.0$		$\pm 0.4$	$\pm 2.0$	mV/mA	
	$T_{\text{MIN}} < T_A < T_{\text{MAX}}$	$\pm 0.5$		$\pm 5.0$	$\pm 0.5$	$\pm 5.0$	mV/mA	
Line Regulation (Note 3)	$T_A = +25^\circ\text{C}$	$\pm 0.01$	$\pm 0.1$		$\pm 0.01$	$\pm 0.1$	mV/V	
	$4\text{V} < V_{\text{IS}} < 30\text{V}$	$\pm 0.02$		$\pm 0.2$	$\pm 0.02$	$\pm 0.2$	mV/V	
Quiescent Current (Note 9)	$V_{\text{S}} = +5\text{V}, +25^\circ\text{C}$	58	80		56	80	$\mu\text{A}$	
	$V_{\text{S}} = +5\text{V}$	105		158	91	138	$\mu\text{A}$	
	$V_{\text{S}} = +30\text{V}, +25^\circ\text{C}$	56.2	82		56.2	82	$\mu\text{A}$	
	$V_{\text{S}} = +30\text{V}$	105.5		161	91.5	141	$\mu\text{A}$	
Change of Quiescent Current (Note 3)	$4\text{V} < V_{\text{IS}} < 30\text{V}, +25^\circ\text{C}$	0.2	2.0		0.2	2.0	$\mu\text{A}$	
	$4\text{V} < V_{\text{IS}} < 30\text{V}$	0.6		3.0	0.6	3.0	$\mu\text{A}$	
Temperature Coefficient of Quiescent Current		$+ 0.39$		$+ 0.7$	$+ 0.39$	$+ 0.7$	$\mu\text{A}/^\circ\text{C}$	
Minimum Temperature for Rated Accuracy	In circuit of Figure 1, $I_{\text{L}} = 0$	$+ 1.5$		$+ 2.0$	$+ 1.5$	$+ 2.0$	$^\circ\text{C}$	
Long Term Stability	$T_{\text{L}} = T_{\text{MAX}}$ for 1000 hours	$\pm 0.08$			$\pm 0.08$		$^\circ\text{C}$	

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  $10 \text{ mV}/^\circ\text{C}$  times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in  $^\circ\text{C}$ ).

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.

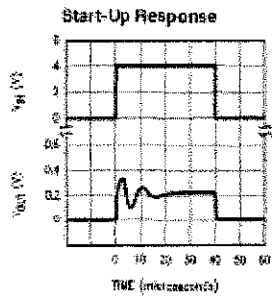
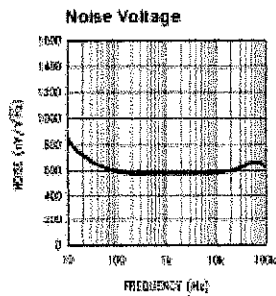
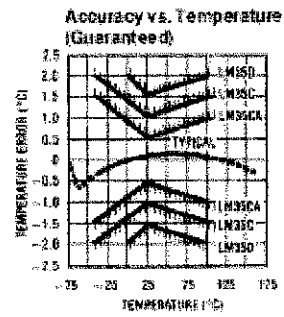
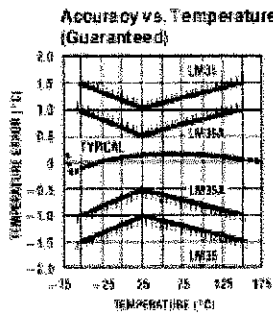
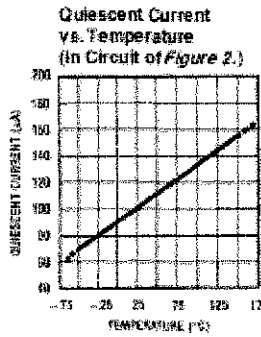
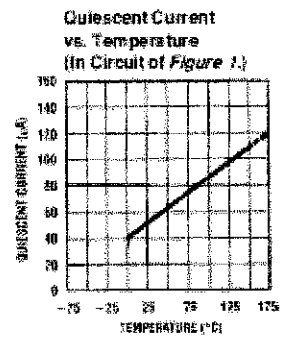
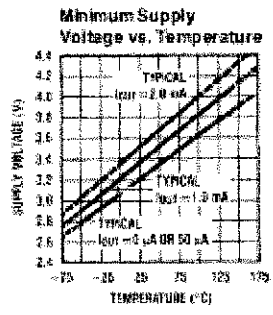
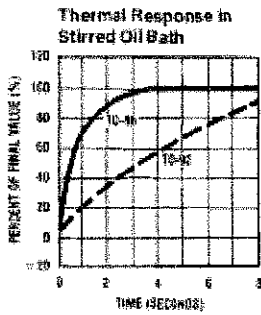
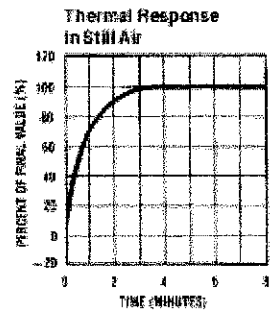
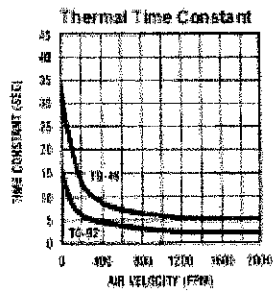
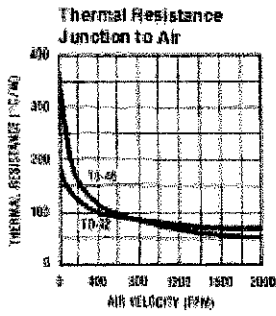
Note 9: Quiescent current is defined in the circuit of Figure 1.

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 k $\Omega$  resistor.

Note 12: See AN-430 "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.

# Typical Performance Characteristics





# APPENDIX C

## PIC16F87X DATASHEET



# PIC16F87X

## 28/40-pin 8-Bit CMOS FLASH Microcontrollers

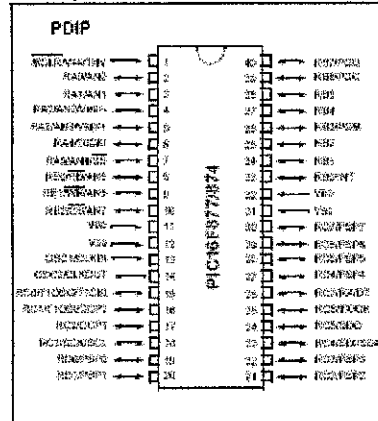
**Devices Included in this Data Sheet:**

- PIC16F873                      • PIC16F876
- PIC16F874                      • PIC16F877

**Microcontroller Core Features:**

- 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 256 x 8 bytes of Data Memory (RAM)  
Up to 256 x 8 bytes of EEPROM data memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (FWRT) and  
Oscillator Start-Up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC  
oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS FLASH/EEPROM  
technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two  
pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.6V
- High Sink/Source Current: 25 mA
- Commercial and industrial temperature ranges
- Low-power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

**Pin Diagram**



**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
- 10-bit multi-channel Analog-to-Digital converter
- 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 RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for  
Brown-out Reset (BOR)

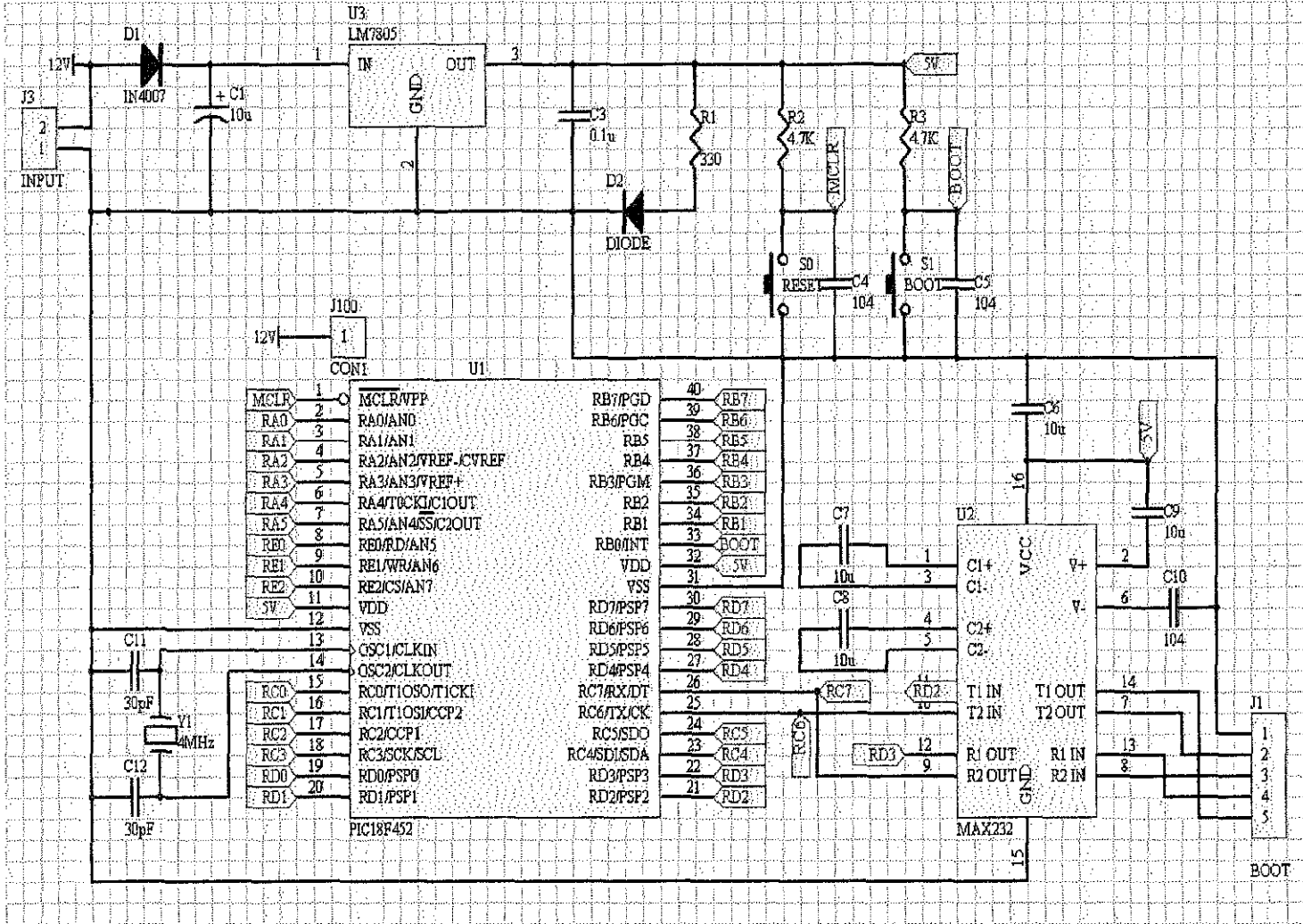
## PIC16F87X

Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	384	384
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	2	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	6 input channels	5 input channels
Instruction Set	35 Instructions	35 Instructions	35 Instructions	35 Instructions

Pin	Description	Pin	Description
1	MCLR – Master clear	40	RB7 – PORT B bit 7
2	RA0 – PORT A bit 0	39	RB6 – PORT B bit 6
3	RA1 – PORT A bit 1	38	RB5 – PORT B bit 5
4	RA2 – PORT A bit 2	37	RB4 – PORT B bit 4
5	RA3 – PORT A bit 3	36	RB3 – PORT B bit 3
6	RA4/T0CK1 – PORTA bit 4/ Counter clk	35	RB2 – PORT B bit 2
7	RA5 – PORT A bit 5	34	RB1 – PORT B bit 1
8	RE0 – PORT E bit 0	33	RB0/INT – PORT B bit 0
9	RE1 – PORT E bit 1	32	Vdd - + V supply
10	RE2 – PORT E bit 2	31	Vss – Gnd
11	Vdd - + V supply	30	RD7 – PORT D bit 7
12	Vss – Gnd	29	RD6 – PORT D bit 6
13	OSC1 / CLK IN	28	RD5 – PORT D bit 5
14	OSC2 / CLK OUT	27	RD4 – PORT D bit 4
15	RC0 – PORT C bit 0	26	RC7 – PORT C bit 7
16	RC1 – PORT C bit 1	25	RC6 – PORT C bit 6
17	RC2 – PORT C bit 2	24	RC5 – PORT C bit 5
18	RC3 – PORT C bit 3	23	RC4 – PORT C bit 4
19	RD0 – PORT D bit 0	22	RD3 – PORT D bit 3
20	RD1 – PORT D bit 1	21	RD2 – PORT D bit 2

APPENDIX D

CYTRON SK40A SCHEMATIC



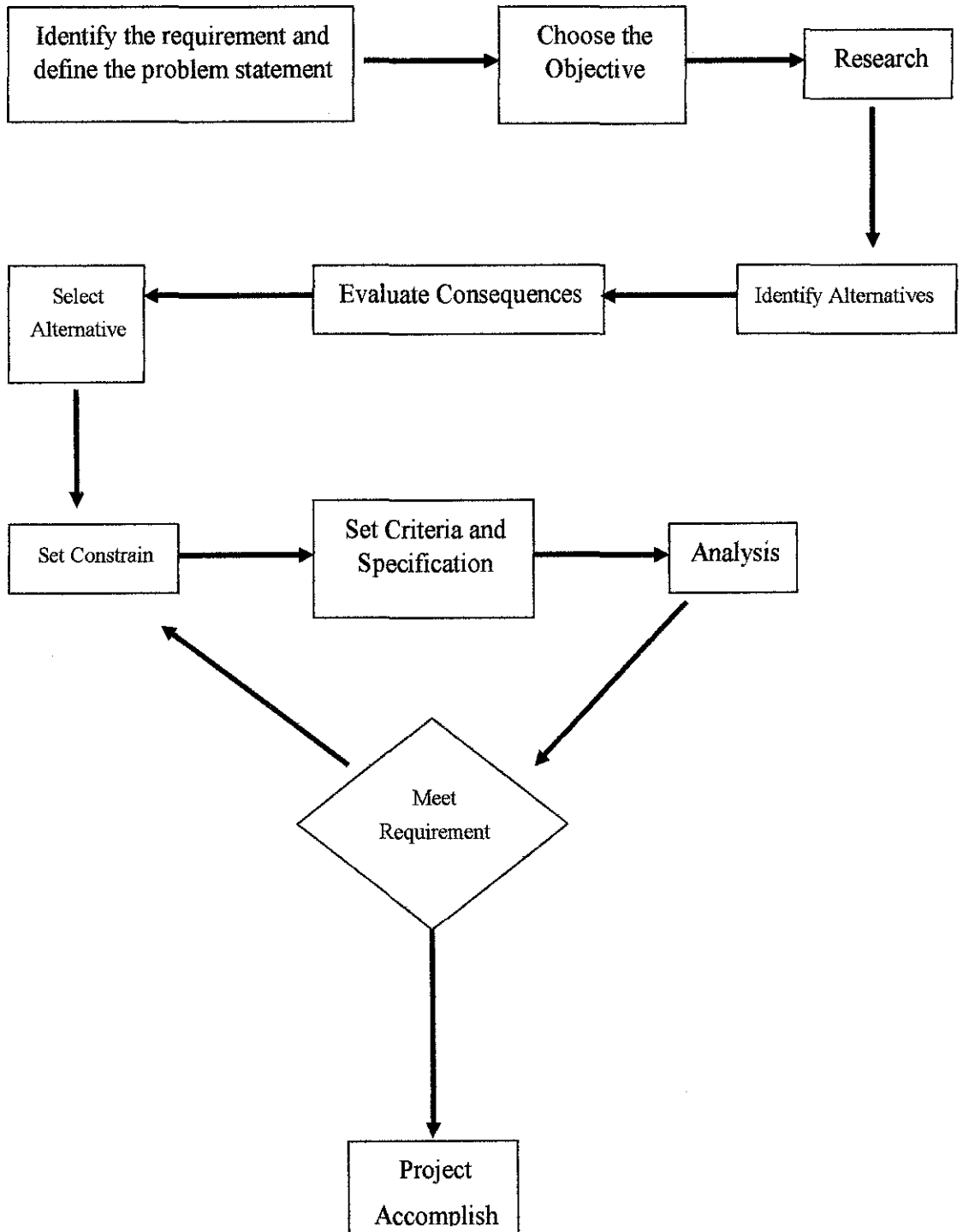
NAME MOHD ZULKIFLI BIN HAMZAH  
 SID 5599  
 H/P 019-9657030  
 E-MAIL pelizoli1410@yahoo.com  
 TOPIC Heat and Rain Detection System for Power Window in Vehicle

APPENDIX E  
 GANTT CHART FYP 1

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic	█	█												
2	Preliminary Research Work		█	█	█										
	2.1 Introduction		█	█	█										
	2.1.1 Background of Project		█	█	█										
	2.1.2 Define Problems Statement		█	█	█										
	2.1.3 Identify the Objectives		█	█	█										
	2.2 Literature Review		█	█	█										
	2.2.1 Background of Power Window Mechanism		█	█	█										
	2.2.2 Sensor Module		█	█	█										
	2.2.3 Power Window Motor Module		█	█	█										
	2.2.4 Microcontroller Module		█	█	█										
	2.3 Project Methodology				█										
3	Submission of Preliminary Report				█										
4	Seminar 1 (Optional)					█	█	█	█						
5	Project Work					█	█	█	█						
	5.1 Data Gathering and Lab Work					█	█	█	█						
	5.1.1 Check Sensor and Motor functions					█	█	█	█						
	5.1.2 PIC chip research					█	█	█	█						
	5.1.3 Analyze the Programming					█	█	█	█						
	5.2 Project Analysis						█	█	█						
6	Submission of Progress Report								█						
7	Seminar 2 (Compulsory)									█	█	█	█		
8	Project Work Continues									█	█	█	█		
	8.1 Heat and Rain Detection System Design									█	█	█	█		
	8.1.1 Set Constraint									█	█	█	█		
	8.1.2 Set Criteria and Specification									█	█	█	█		
9	Submission of Interim Report Final Draft ( soft bound )													█	
10	Oral Presentation														█

Mid-Semester Break

**APPENDIX F**  
**FYP I WORK FLOW**



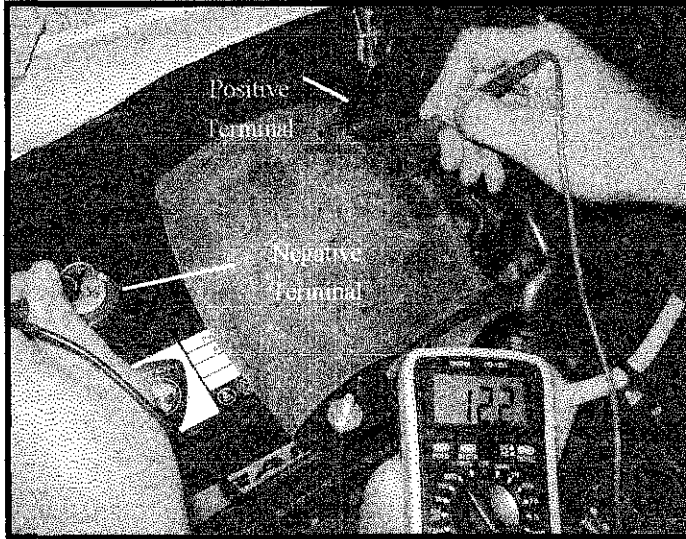




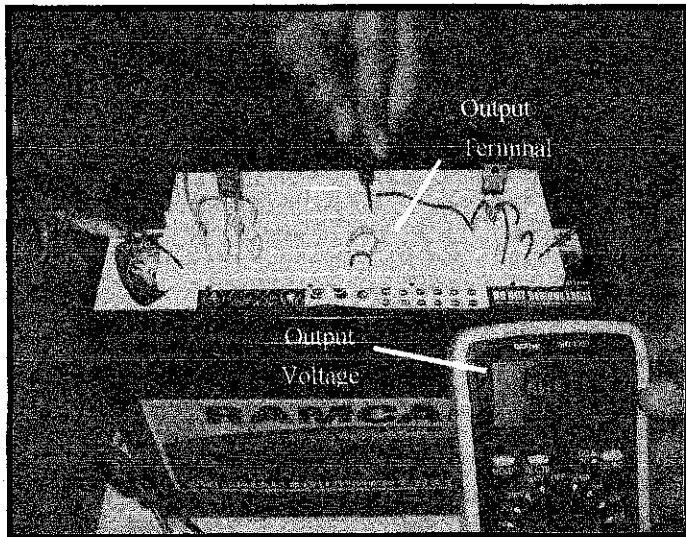


# APPENDIX H

## POWER SUPPLY TESTING



The Voltage of Car Battery



The Output Voltage of Power Supply Circuit

# APPENDIX I

## COMMENTED PROGRAM CODE

### \* Description:

The code demonstrates using library function for AD conversion.

10 bits result is using to move the stepper motor by angle (1.8 degree) and using the sensor to detect water

### \* Test configuration:

MCU: P16F877A  
Dev.Board: PICkit 2  
Oscillator: HS, 20.0000 MHz  
Ext. Modules: x  
SW: mikroC v 2.1.0.0

\*/

```
//-----define I/O-----  
#define water PORTD.F7  
#define water1 PORTD.F6  
#define limit PORTB.F2  
#define sw_up PORTB.F7  
#define sw_down PORTB.F5  
  
//-----function prototype-----  
void step_stop();  
void step_up();  
void step_down();  
  
//-----main prog-----  
unsigned int temp_res;  
  
void main()  
{
```

```

OPTION_REG = 0x80;           // disable interrupt
ADCON1     = 0x80;           // configure VDD as Vref, and analog channels
TRISA      = 0xFF;           // designate porta as input
TRISD.F7   = 1;
TRISD.F6   = 1;
TRISD.F5   = 0;
TRISD.F4   = 0;
TRISD.F3   = 0;
TRISD.F2   = 0;
TRISD.F1   = 0;
TRISD.F0   = 0;             // designate portd as output and input
TRISC      = 0xFF;           // designate portc as input
TRISB      = 0x00;
Delay_ms(2000);

while(1)
{
temp_res = ADC_Read(1); // Get results of AD conversion

if (sw_down == 1)
{step_down();}

else if(sw_up == 1)
{step_up();}

else
{if ( temp_res >= 0x15E ) // temp_res >= 36 degree Celsius
{ while(limit == 0)
{step_down();}
}
}
}

```

```

else if(( water1 == 1) ||(water == 1) ) // detect water
{ while (limit == 1)
{step_up(); } }
}

}
}
//-----step_down-----

```

```

void step_down()
{
int a;

while( a < 200)
{
PORTB = 0x09; //rotation in cw direction
Delay_ms(196);
PORTB = 0X0A;
Delay_ms(196);
PORTB = 0X06;
Delay_ms(196);
PORTB = 0X05;
Delay_ms(196);
a = 0;
a++;
}
}

```

```

//-----step_up-----

```

```

void step_up()
{
int b;

```

```

while ( b < 200)
{
    PORTB = 0X05;    //rotation in CCW direction
    Delay_ms(196);
    PORTB = 0X06;
    Delay_ms(196);
    PORTB = 0X0A;
    Delay_ms(196);
    PORTB = 0X09;
    Delay_ms(196);
    b =0;
    b++;
}
}

```

//-----step\_stop-----

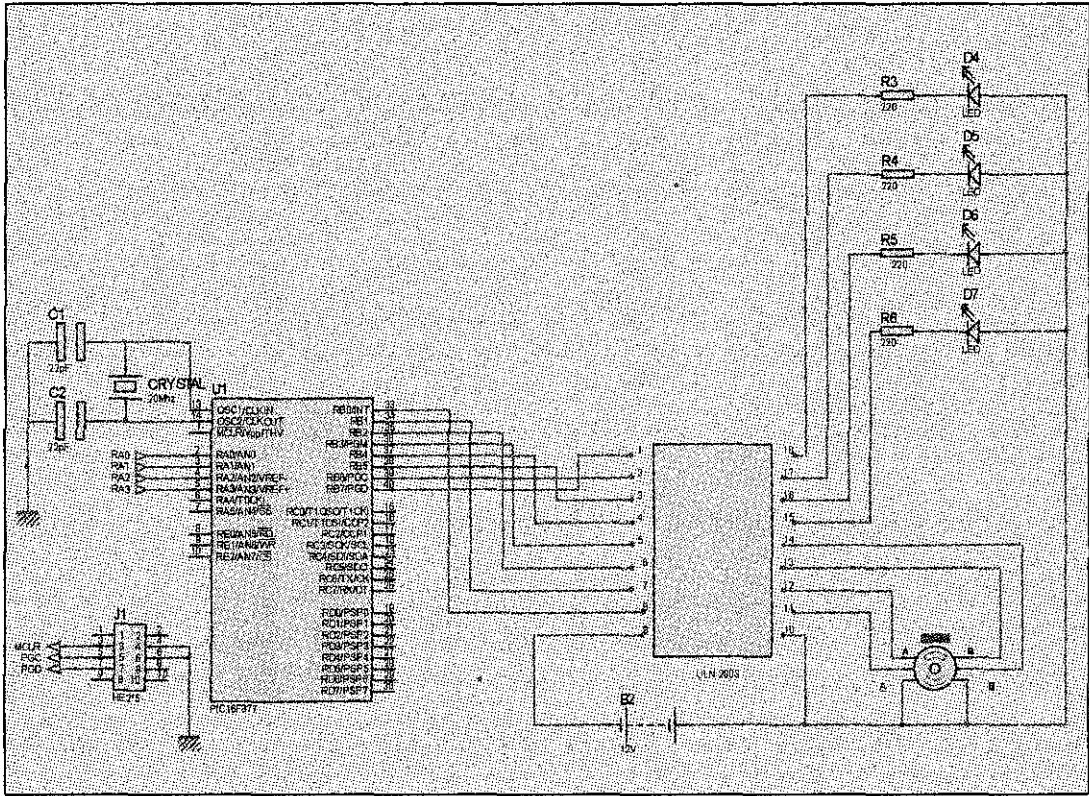
```

/*void step_stop()
{
while(1)
{
    PORTB = 0x06;    //hold the motor stepping
    Delay_ms(196);
    PORTB = 0x05;
    Delay_ms(196);
    PORTB = 0x09;
    Delay_ms(196);
    PORTB = 0xA;
    Delay_ms(196);
}
}*/

```

# APPENDIX J

## PIC CIRCUIT



# APPENDIX K

## ULN 2803 DATASHEET

**TOSHIBA**

ULN2803,04APG/AFWG

TOSHIBA Bipolar Digital Integrated Circuit Silicon Monolithic

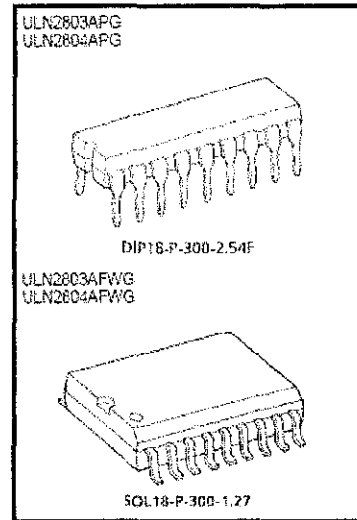
**ULN2803APG, ULN2803AFWG, ULN2804APG, ULN2804AFWG**  
(Manufactured by Toshiba Malaysia)

### 8ch Darlington Sink Driver

The ULN2803APG / AFWG Series are high-voltage, high-current darlington drivers comprised of eight NPN darlington pairs. All units feature integral clamp diodes for switching inductive loads. Applications include relay, hammer, lamp and display (LED) drivers. The suffix (G) appended to the part number represents a Lead (Pb)-Free product.

### Features

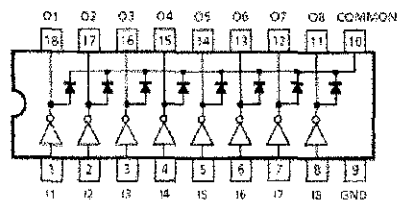
- Output current (single output)  
500 mA (Max.)
- High sustaining voltage output  
50 V (Min.)
- Output clamp diodes
- Inputs compatible with various types of logic.
- Package Type-APG : DIP-18pin
- Package Type-AFWG : SOL-18pin



Weight  
DIP18-P-300-2.54F : 1.478 g (Typ.)  
SOL18-P-300-1.27 : 0.46 g (Typ.)

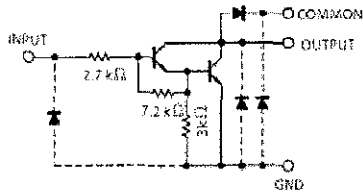
Type	Input Base Resistor	Designation
ULN2803APG / AFWG	2.7 kΩ	TTL, 5 V CMOS
ULN2804APG / AFWG	10.5 kΩ	5-15 V PMOS, CMOS

### Pin Connection (top view)

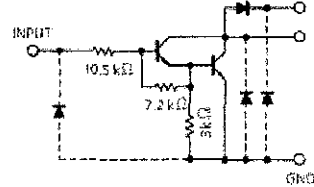


**Schematics (each driver)**

ULN2803APG / AFWG



ULN2804APG / AFWG



Note: The input and output parasitic diodes cannot be used as clamp diodes.

**Absolute Maximum Ratings (Ta = 25°C)**

Characteristic	Symbol	Rating	Unit
Output sustaining voltage	V <sub>CE (SUS)</sub>	-0.5-50	V
Output current	I <sub>OUT</sub>	500	mA/ch
Input voltage	V <sub>IN</sub>	-0.5-30	V
Clamp diode reverse voltage	V <sub>R</sub>	50	V
Clamp diode forward current	i <sub>F</sub>	500	mA
Power dissipation	APG	P <sub>D</sub>	W
	AFWG		
Operating temperature	T <sub>opr</sub>	-40-85	°C
Storage temperature	T <sub>stg</sub>	-55-150	°C

Note: On Glass Epoxy PCB (75 × 114 × 1.6 mm Cu 20%)