CERTIFICATION OF APPROVAL

MICROCONTROLLER-BASED ELECTRONIC LPG DETECTOR

by

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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 by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2004

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.

NURUL SHAZRAH MOHD SARIFFUDDIN

ABSTRACT

The report is written to present the work done on the Final year project entitled 'Microcontroller-based Liquefied Petroleum Gas (LP-Gas) Detector'. This project aim is to design a device such that can detect the concentration of gas in a chamber or a small compartment such as a kitchen using the gas resistance drop technique.

This project focuses on designing and implementing a gas detector unit for LP-gas detection. The input of the gas detector comes from the output of the MQ-6 gas sensor. If the concentration is high, the output voltage of the sensor rises. The microcontroller which is embedded in the detector circuit acts as the brain for the detector. If the concentration of the gas is at critical or dangerous limit, it produces warning outputs via the warning LED and buzzer. Automatic exhaust fan will also be activated to vent-out the excess gas if the concentration should rise higher.

The microcontroller is programmed to work as such by using the special language called 'assembly language'. This language interprets whatever the data input to it to binary numbers so that it can perform the command programmed by the programmer.

In order to successfully implement this project, researches on the topic selected and feasibility studies were carried out. Problem of the project is identified before the conceptual design. With the concept clarified, the model construction is done followed by experimentation and programming the source code. After a numerous testing and troubleshooting, a prototype gas detector unit is finally designed.

ACKNOWLEDGEMENTS

First of all, deepest gratitude goes to the supervisor, Dr. John Ojur Dennis for his guidance and patience in ensuring that the author accomplishes the objective of this project. Greatest thanks to Head of Electrical & Electronics Engineering Department, Associate Professor Dr Mohd Noh Karsiti and other Electrical & Electronics lecturers, as well as technicians from Electrical & Electronics Department, especially Miss Siti Hawa for her patience and helpful assistance.

The author also would like to express a thousand appreciations to colleagues for all the kindness, help, guidance and commitment throughout the year.

The gratitude extended to author's parents who gave undivided support to the author throughout the completion of the project. The author will always be grateful for their sacrifices and sincerity.

Finally, million thanks to all parties who had also contributed directly or indirectly to the success of this project.

Thank you.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

In most homes, combustion gases are produced by appliances such as gas-fired furnace, boiler, water heater or other fuel-burning devices. Normally, these combustion products — which can include both visible smoke and various invisible gases — should be vented to the outdoors. Unfortunately, they may instead escape into our home, where they could raise a variety of health and other concerns. Since flammable and toxic elements present in combustion gases are hardly detectable with human senses, this project shall implement a domestic gas detector which shall detect Liquefied Petroleum Gases (LP Gases) such as propane and butane and warn the owner when a certain gas concentration is exceeded. Existing gas detectors are mostly DC powered and this may consumed a lot of batteries, and thus increasing the operating costs.

1.2 Problem Statement

1.2.1 Problem Identification

This project focuses on designing and implementing a microcontroller-based electronic gas detector which detects concentration of LP Gas and warns the user via audible alarm if the Lower Explosive Limit (LEL) is reached. The gas detector will also automatically actuate a fan to vent-out the gases to reduce the concentration to normal state. The operating environment will include residential domains or normal household conditions. It shall be used for domestic purposes only, may not be exposed to adverse environment for a long term, and should not have excessive vibrations or contact with water. It will be powered by AC supply or otherwise known as mains supply. The type of microcontroller (the brain of the detector) that will be used is PIC 16F877 because of its simplicity. The program to control the detector is written in assembly language.

1.2.2 Significant of the Project

The Liquefied Petroleum Gas (LP Gas) is an energy source that is commonly used in homes for cooking and heating. It is primarily composed of propane and butane. Although it only happens rarely, a LP gas leak can sometimes occur inside the home. A LP gas leak can be dangerous because it increases the risk of fire or explosion. Since propane and butane naturally does not have any odor, the gas company adds a warning "rotten-egg" smell (the stanching smell which is from mercaptan or a similar sulfur-based compound) that can be easily detected by most people. However, people who have a diminished sense of smell may not be able to rely upon this safety mechanism. A gas detector can be an important tool to help protect our homes. The microcontroller installed is for automatic response so that in case when the LEL of LP Gas is reached, it will give out immediate alarm and start actuating the fan which will vent out the gas until the atmosphere returns to normal concentration. By constructing the prototype, in the end we would have a low-cost mains-supplied detector which can be used in homes.

Exposure to low levels of LP gas is not harmful to health. However, if a gas leak is severe, the amount of oxygen available for breathing could be dramatically reduced, which can lead to asphyxia. Symptoms of asphyxia include

- dizziness
- fatigue
- nausea
- headache
- irregular breathing

Exposure to extremely high levels of LP gas can cause loss of consciousness or even death. The other hazard is the flammability of the gas when it reaches a certain concentration level in air known as the Lower Explosive Limit (LEL).

1.3 Objectives and Scope of Study

1.3.1 Objectives

The objectives of this project are:

- To design and simulate a microcontroller gas detector using appropriate tools and methodology.
- To construct a prototype of the microcontroller-based gas detector.
- To come up with a design which is cost effective, simple to use and easy to set up.

1.3.2 Scope of Study

The scope of this project takes into consideration the study of LP Gas characteristics, its permissible limits, the sensor and the microcontroller function, programming the assembly language for the PIC16F877 microcontroller, the design and the simulation of the circuits according to requirements set by supervisor.

On the hardware side, the simulated design is wired nicely on a veraboard and presented in the form of a complete gas detector unit, in other words, producing a gas detector unit which has low-cost, long life and good sensitivity to the target gas detected. At the end of this project, a prototype gas detector will be developed that can be used in homes or perhaps small labs which involve the use of LP Gas. This project has exposed the author to microcontroller programming and digital electronics design and resulted in a hands-on experience in order to complete the task in a given time frame.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 Liquefied Petroleum Gas (LP Gas)

The consequences of a LP gas leak at home can be disastrous. Although the gas is not regarded as poisonous, it is explosive and can lead to devastating explosions if it builds up to sufficient levels [1]. The concentration is measured using what's called the Lower Explosive Limit (LEL).

LP Gas is a mixture of light hydrocarbons that are gaseous at normal temperatures and pressures but readily liquefy at moderate pressures or reduced temperatures. The two most common LP gases are propane and butane [2].

LP Gas is usually stored as a liquid under pressure. When released into the atmosphere at any temperature above its boiling point (-42°C for Propane and 0°C for Butane) it will change from a liquid to vapor. Liquid LPG on bare skin causes frostbite. LP Gas is heavier than air. In both its liquid and vapor sates, it is colorless and odorless. A stenching agent is added to enable any leaks to be detected by smell [3].

2.2 Lower Explosive Limit

The Lower Explosive Limit (LEL) is the lowest amount of gas that will cause an explosion. The alarm threshold is equal to a concentration of 0.35% (3,500 ppm) of Propane-LPG, which corresponds to about 16% of LEL. The regulations require that the alarm threshold is below 25% of LEL [4]. From the Henan Henwai website on the MQ-6 sensor [5], the LEL for LP gas is at 3%. The whole table can be viewed as in APPENDIX 1.

2.3 MQ-6 Liquefied Petroleum Gas (LP Gas) Sensor

The gas detector shall be implemented using a semiconductor sensor, the MQ-6 which, are suitable for detecting of LP Gas .It has high sensitivity to LP Gas, iso-butane, propane ,fast response, small sensitivity to smoke, simple drive circuit, stable and has long life [5].

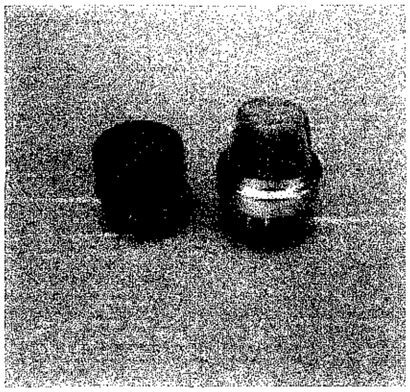

Figure 2.1: MQ-6 Sensor

2.3.1 Basic Sensor Circuit

Basically Figure 2.2 shows how the basic sensor circuit looks like. The comparator is added to measure and compare the load voltage (V_{RL} and the reference voltage (V_{REF}).

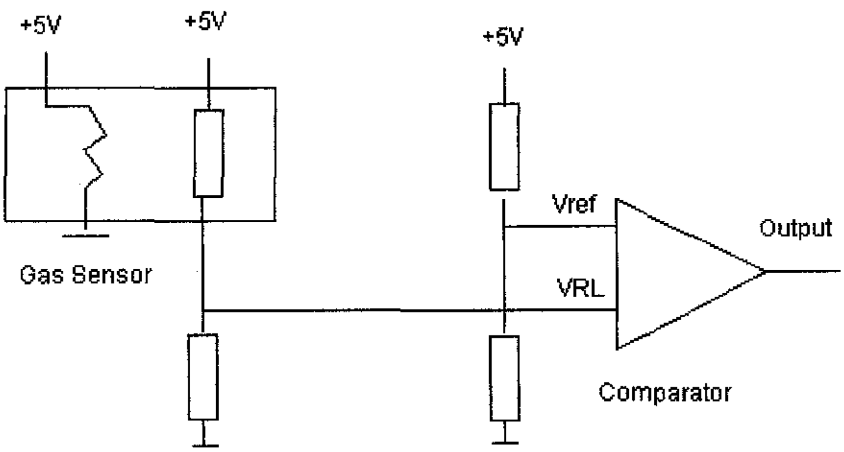

Figure 2.2: Basic Sensor Circuit

2.3.2 Sensitivity of MQ-6 sensor

The feature of the MQ-6 sensor is that it has high sensitivity to LPG, iso-butane and propane and small sensitivity to alcohol and smoke. Figure 2.3 shows the typical sensitivity characteristics of the MQ-6 for several gases at temperature of 20 degrees, oxygen concentration at 21% and RL equals to 20 kΩ. Ro in the figure refers tothe sensor resistance at 1000 ppm of LPG in clean air and Rs refers to the sensor resistance at various concentration of gases

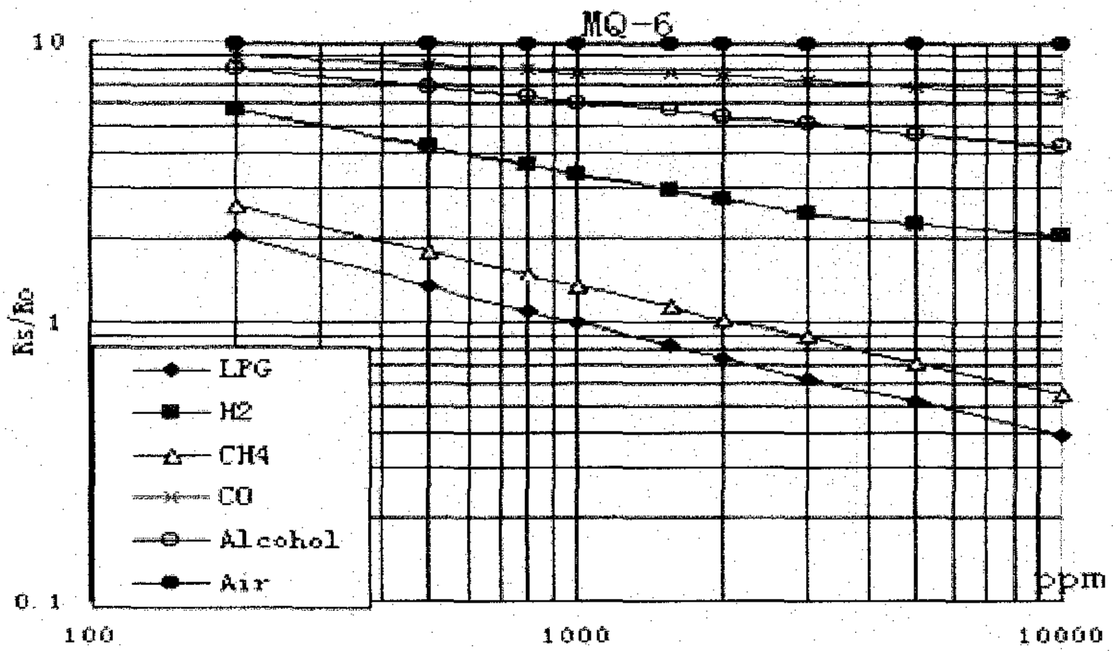

Figure 2.3: Sensitivity Curve for MQ-6 Sensor

The relationship between sensor resistance and the concentration of deoxidizing gas can be expressed by the following equation over a certain range of gas concentration:

$$R = nC - m(\log(Rs) = -m\log C + n)$$

.... Equation 2.1

where R is the electrical resistance of the sensor, C is the gas concentration and *m and n are* constants. *m* represents the sensitivity according to the change of gas concentration , *n* is relevant to sensitivity to the detected gas, concomitancing the difference with different sensors ,gas variety ,and detecting terms .

According to the Equation 2.1, the relationship of sensor resistance to gas concentration is linear on a logarithmic scale within a practical range of gas concentration (from several ppm to several thousand ppm). Figure 2.3 shows a typical example of the relationship between sensor resistance and gas concentration. The sensor will show sensitivity to a variety of deoxidizing gases, with relative sensitivity to certain gases optimized by the formulation of sensing materials and operating temperature. Since actual sensor resistance values vary from sensor to sensor, typical sensitivity characteristics are expressed as a ratio of sensor resistance in various concentrations of gases (Rs) over resistance in a certain concentration of a target gas (Ro). Since sensor resistance varies as a logarithmic function of gas concentration, therefore sensitivity characteristics to a certain gas differs with sensor type.

When measuring a certain gas, possible interference of co-existing gases must always be taken into consideration. For example, when measuring an atmosphere containing both Propanol and Ethanol, the Propanol measurement can be affected by the Ethanol.

Resistance value of the same sensor is different to various kinds and various concentration gases. Resistance value of various sensors has difference to the same gas concentration too. Thus, when using this component, sensitivity adjustment and calibration is very necessary to every sensor. In addition, when accurately measuring, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence.

2.3.3 Temperature and Humidity Dependency

The sensing principle of semi-conductor sensor is based on chemical adsorption and desorption of gases on the sensor's surface, meaning that the ambient temperature and humidity will affect sensitivity characteristics easily. According to the above, a compensation circuit for temperature dependency must be considered when using the MQ-6 sensor in the gas detector for better reliability and accuracy. Figure 2.4 shows a typical example of these dependencies. Ro in the figure refers to the sensor resistance at 1000ppm of LPG in air at 33%RH and 20 degree. Rs on the other hand refers to the sensor resistance at 1000ppm of LPG in air at different temperatures and humidities.

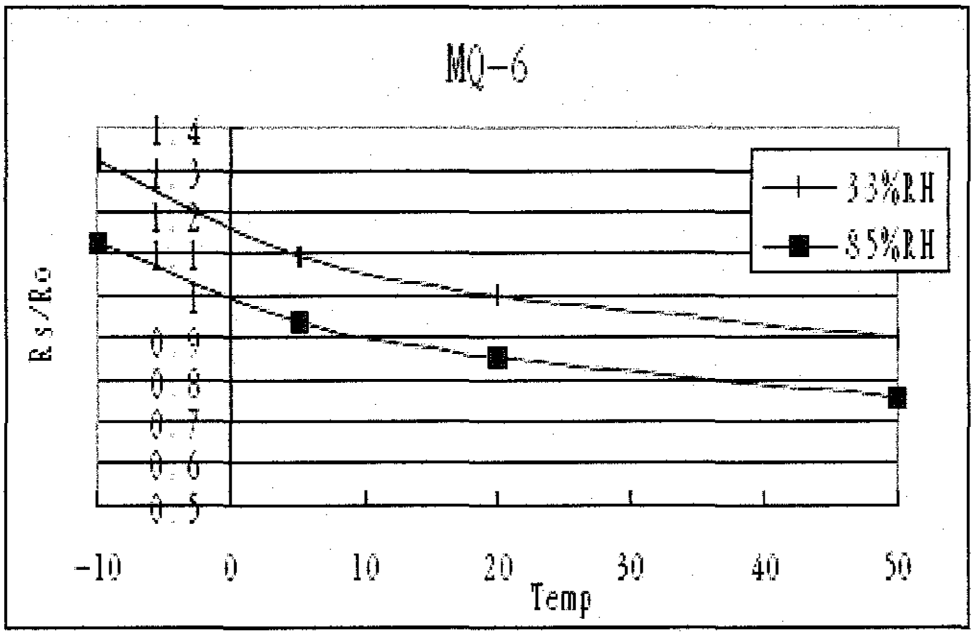

Figure 2.4: Temperature and Humidity Dependency for MQ-6 sensor

Figure 2.5 shows the compensation circuit with thermistors (Rt) for temperature. The circuit in this figure is used as reference for simulation in the Electronics Workbench (EWB) to obtain the voltage and current for the circuit in order to analyze the response of the circuit to different resistance of the sensor circuit.

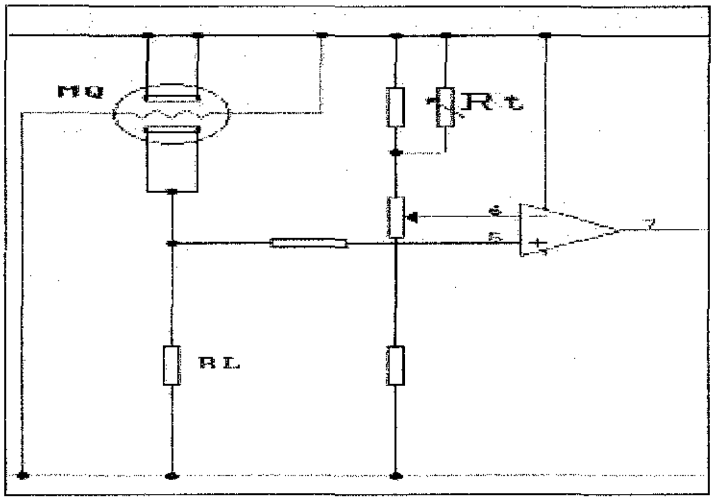

Figure 2.5: Compensation Circuit

2.3.4 Sensor Response

Figure 2.6 demonstrates typical behavior when the sensor is exposed to and then removed from a deoxidizing gas. Sensor resistance will drop very quickly when exposed to gas, and when removed from gas its resistance will recover to its original value after a short time. The speed of response and reversibility will vary according to the MQ-6 sensor and the LP-Gas that it sense.

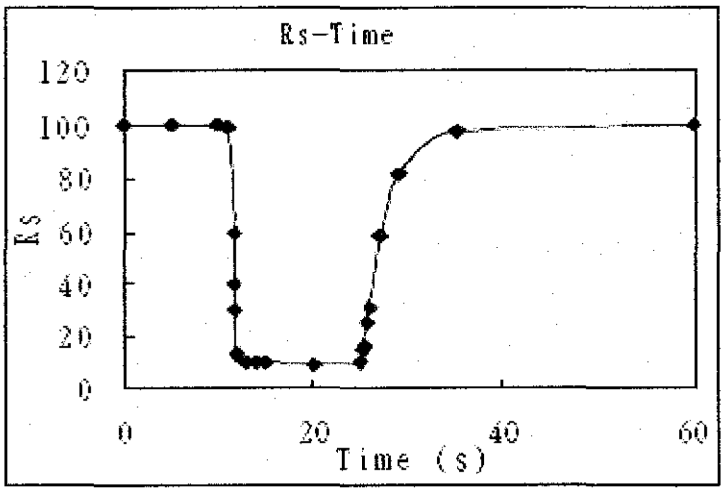

Figure 2.6: The sensor resistance response to gas concentration versus time

One way to analyze the sensor behavior is by using PASCO 750 together with Data Studio. By using the PASCO, the data gathered for the first hour of heating will show that the voltage varies largely during start up of the heating process. At about five minutes later, the graph will decay to stabilize back and only fluctuate a little along the way. The voltage value during the preheating process (less than 34 hours) is around 0.6 to 0.7 V.

After 24 hours of the preheating process, the graph will be seen to stabilize between 0.6 to 0.8V. This indicates that the sensor is ready to operate as it had been heated completely. The graph will show an almost constant reading for as long as there is no external factor that needed it to change its resistance such as humidity or high temperature. Once the sensor is exposed to LPG gas, the graph shoots up to a certain voltage higher than the 0.6~0.8V reading. Although the voltage rise can go as high as 3.0V, the sensor is quick to stabilize back once the concentration of the gas is no longer there. It normally takes approximately 30 seconds before the sensor stabilizes back to its normal value of 0.6 to 0.8V [14].

The purpose of carrying out this experiment is to observe the response of the gas sensor towards the target gas. Other than that, it can also be used to verify the theoretical value of the sensor resistance in the data sheet.

2.3.5 Long-term Stability

To determine the stability of the sensor, the sensor is first energized in normal air. Measurement for confirming sensor characteristics is conducted under ambient air conditions rather than in a temperature/ humidity controlled environment. The cyclic change in sensitivity corresponds to the seasonal changes of temperature/humidity. During these measurements, the gas sensors are powered in a clean atmosphere and then exposed to a gas at certain intervals. It should be noted that sensors will not function normally when continuously exposed to a certain concentration of gas.

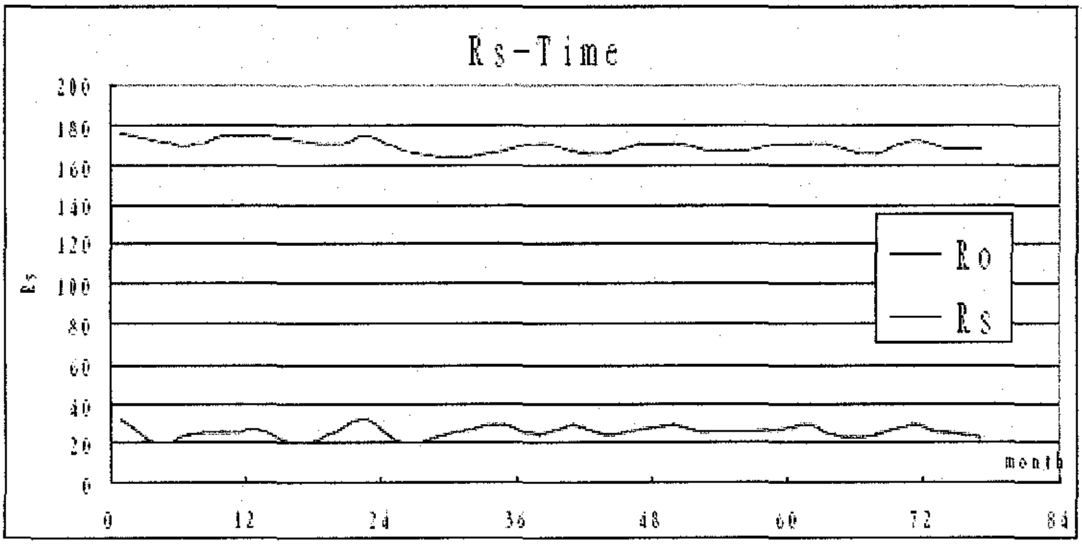

Figure 2.7: The cyclic change in sensitivity vs seasonal changes of temperature/humidity

2.4 The PIC16F877 Microcontroller

The 16F877 is the microcontroller that is used in the design because it makes the detector much simpler. The chip can be programmed to perform operations based on the chip inputs and outputs. To get started to use these chips, two pieces of hardware and two pieces of software is needed [7].

Hardware

1. The Hardware Programmer
2. The circuit to test the inputs and outputs of the chip in once it has been programmed

Software

1. To write and compile assembly (.asm) code to a hexadecimal (.hex) file
2. To burn the hex file onto the chip

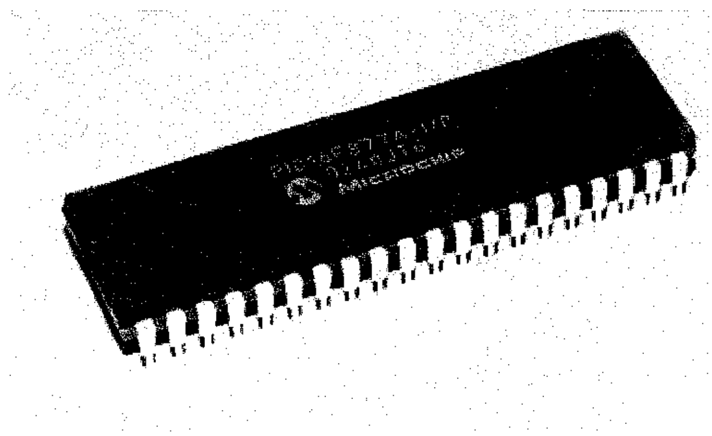

Figure 2.8: PIC 16F877

PIC16F877 features 256 bytes of EEPROM data memory, self programming, an ICD, 8 channels of 10-bit Analog-to-Digital (A/D) converter,2 additional timers, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I^2C™) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications. [8]

Besides the usual In/out ports, the microcontroller also includes PWM (Pulse Width Modulation), a couple of Analog to Digital converters (A/D), and some type of serial communication. The Ports can be configured with the code to be inputs or outputs. We can then read a high or low logic level (inputs) or produce a high or low logic level (outputs). The PWM helps to adjust the duty cycle (how long the output is high or low) of a square wave and adjust the frequency of the square wave by giving the PIC the information in the code. The A/D converters can be used to "read" an analog voltage like the output voltage of the gas sensor. The voltage will then be represented by the PIC as a binary number [9].

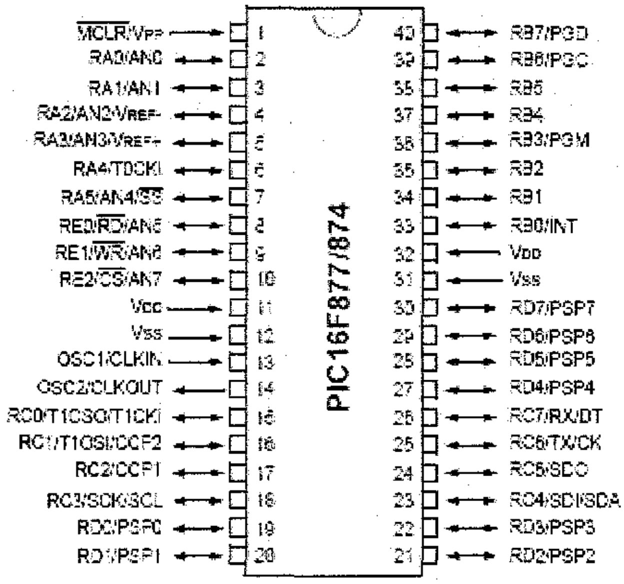

Figure 2.9: The PIC 16F877 Microcontroller pins layout

MPLAB is the free software from Microchip. It compiles the assembly language, helps organize the programs, and interfaces with what ever programmer that is used. It can also be used for debugging of the code.

MPLAB IDE runs as a 32-bit application on MS Windows®, is easy to use and includes a host of free software components for fast application development and super-charged debugging. MPLAB IDE also serves as a single, unified graphical user interface for additional Microchip and third party software and hardware development tools. Moving between tools is a snap, and upgrading from the free simulator to MPLAB ICD 2 or the MPLAB ICE emulator is done in a flash because MPLAB IDE has the same basic user interface for all tools [8].

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

There are six tasks required to be completed for the successful conclusion of the project. These tasks are listed in Table 3.1 and the details are given in the following sections.

Table 3.1: Lists of Tasks for the Project

Task 1: Literature review and planning
Task 2: Gas sensor circuit design, study examples from templates and solution available in the market
Task 3: Programming the language and loading it into the 16F877
Task 4: Testing the circuit, testing the program
Task 5: Producing final hardware
Task 6: Final report and presentation

Task 1: The scope of the literature review includes an analysis about Lower Explosive Limit (LEL) of the LP Gas, The MQ-6 gas sensor, gas sensor operation, the microcontroller and the programming language. Sources from books and internet are very useful during this phase. A lot of information is gained through this process and it helps a lot in the progress of the design.

Task 2: Design specification and conceptual design are developed to narrow down the scope and to make easy the design process. By establishing these criteria, the design phase is made easy because all the requirements and constraints are known. Some examples of templates from the existing designs are studied to come out with the conceptual design of the microcontroller gas detector. This task is done by numerous researches from the relevant websites and books from the library.

Task 3:. The microcontroller programming language will be run first on the PC to check for errors before loading it into the PIC. The steps involved in programming the PIC are:

Step 1: Writing the assembly language program
Step 2: Using the compiler
Step 3: Programming the PIC Chip

Thus, PIC program for the gas detector can be loaded up on the computer and the program can be written on it. When writing is finished, it is ready to be assembled. This converts what have been written into a series of numbers which the computer understands and will be able to use to finally 'blow' the PIC. This new program consisting solely of numbers is called the hex code or hex file- a hex file will have .hex after its name. Basically, the 'complicated' PIC language is all a raw program consists of numbers. So, the assembler, a piece of software which comes with the PICSTART or MPLab package-called MPASM (DOS version) or WinASM (Windows version) – translates the words into numbers.

If however it fails to recognize one of the 'words' then it will register an error- things which are definitely wrong. It may register a warning to indicate something which is probably wrong. On the other hand, it may give is a message telling that something which is not wrong, but shows it has had to think a little bit more than usual when 'translating' that particular line.

Once the program has been assembled into a series of numbers, they get fused into ROM (Read Only Memory) of the PIC when we blow the PIC 16F877 and they stay there until we erase it from the PIC.

These are the procedures on how to use MPLAB:

1. Click on project and select new project.
2. Type in a name for the project and press OK. The edit project box comes up.
3. Hit the change button. Make sure to select the part number of the PIC the will be used.
4. Check the "MPLAB ICD Debugger" option. In the project files box click on the name of the project that has been created.
5. Select “add node”. When the "add node" box comes up, type in the same name as when prompted for the project name.
6. Click OK. Now click on File and select New, to open a window to type the program code in.

After the codes are written and compiled, if there are no errors, the microcontroller chip can be burned. The burning process can be done using the MPLab. However, for this project, the Warp 13 is used since the application is much easier to apply and less time consuming.

Task 4: The testing for the detector is divided to two parts. The first test is on the sensor circuit. Then, the microcontroller code is debugged and tested using the circuit constructed before.

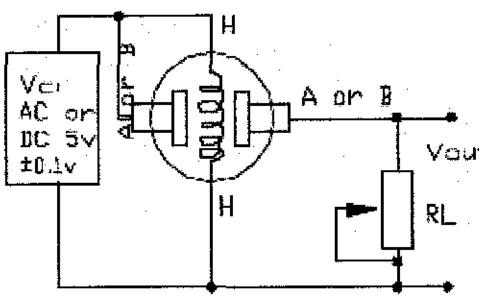

Figure 3.1: The MQ-6 Sensor Circuit

The gas sensor circuit can be tested by connecting the circuit as in the figure above. When the sensor absorbs the LP Gas, the voltage will rise up to just below 5 V. When the gas dissipates, the voltage goes down.

For the demo, all the circuits used are enclosed in a box which represents the gas detector unit. The LP Gas is released near the gas sensor. The gas detector will be on by providing power to the units from the mains supply. The detector is preheat for 2 minutes. When the LP gas concentration reaches LEL, the response of the detector is observed. When the sensor has sensed the gas adequately, the buzzer will sound and the red LED lights up. If the level rises to higher concentration, the fan will be actuated to vent-out the gas.

Task 5: The initial hardware was constructed by using the breadboard. After that, the circuit is transferred onto the veraboard for much stable performance and neater look. The final hardware will have the gas detector circuit in a box where it can be placed anywhere inside our homes.

Task 6: The final report and presentation will be carried out as scheduled.

3.2 Tools Required

This project requires integration of software and hardware in order to produce a desired model or design. Table 3.2 shows some of the components used to build the gas detector. This means, along with the PIC 16F877 a collection of LEDs, 330 and 4.7K Resistors, 0.1 uF caps for decoupling, some switches and miscellaneous parts for different applications are also needed.

Table 3.2: Component Listings

	Hardware requirements:	**Software requirements**
1.	VeraBoard	Electronics Work Bench (EWB)
2.	Microcontroller (PIC16F877)	MPLab
3.	Crystal Oscillator	WARP-13 – Microchip PIC Programmer
4.	MQ-6 sensor	
5.	Fan	
6.	Light Emitting Diode (LED)	
7.	Buzzer	
8.	resistors, capacitors, relay, transistors	

CHAPTER 4

RESULTS & DISCUSSION

4.1 Characteristics of MQ-6 Gas Sensor

The heart of the electronic gas detector is MQ-6 sensor which senses the LP Gas. The concentration of the gas will be determined via a unique relationship between the concentration of the gas and the internal sensor resistance

The gas detector circuit is designed to measure an the alarm threshold which is equal to a concentration 0.48% (4,800 ppm) of LP gas in the air, which corresponds to about 16% of LEL (lower explosive limit). The regulations require that the alarm threshold is below 25% of LEL. LEL for LP Gas for the MQ-6 sensor = 3.0 % (30,000ppm) as indicated in Table 4.1. This means that, once the sensor detects the 0.48% of LEL, the first alarm will trigger.

Table 4.1: The MQ-6 and LP-Gas relation

Gas Name	LEL(%)	Gas Proportion (air=1)	Toxicity
LP-Gas	3	>1	asphyxiation

This sensor is suitable for detecting of LP gas since it avoids the noise of alcohol, cooking fumes and cigarette smoke. The gas sensor is implemented in a circuit as shown in Figure 4.1 and discussed in Section 4.2.

4.2 Gas Sensor Circuit Simulation

The circuit design for the MQ-6 sensor is as in Figure 4.1. The circuit comprises of some resistors, a comparator, transistor and LED-which indicates the buzzer. In this circuit, the MQ-6 sensor is represented as variable resistor. The circuit in here is used only for simulation. In the actual circuit design, only a 20 kΩ resistor is put in series with the MQ-6 sensor.

For the simulation, various R_L value for the circuit in Figure 4.1 is simulated. The voltage drop for each of these resistance values after the simulations are noted. The result of the simulation is as given in Table 4.2. For this range of R_L, the typical LP-Gas detection ranges from 300 to 100000ppm. Although the table indicates the values of V_{ref}, V_{RL} and I_L for different resistor values, we are only interested in the value of V_{RL}.

Table 4.2: Results for simulation at *V_C = 5V and I_T= 413.9 mA

R_L	5kΩ	20kΩ	40kΩ	400kΩ
V_{ref}	2.619 V	2.619 V	2.619 V	2.626 V
V_{RL}	4.282 V	4.779 V	4.981 V	4.983 V
I_L	0.7mA	0.239mA	0.12mA	0.012mA

*Vc is the voltage supplied to the sensor circuit which is 5V.

The relationship between the sensor resistance, Rs and the load resistance, R_L is given by the following expression;

$$Rs = \frac{R_L(Vc - V_{RL})}{V_{RL}}$$

..........Equation 4.1

Taking the value of R_L to be 5 kΩ, the V_{RL} is 4.282 V and the value of Rs is found to be 838.39Ω. If the value of R_L is taken to be 40 kΩ, the resulted Rs would be 152.6Ω. At R_L = 400 kΩ, the Rs is 1364.6Ω. Using R_L = 20 kΩ as recommended in the MQ-6 datasheet, the value of the sensing resistance is found to be 973.15Ω.

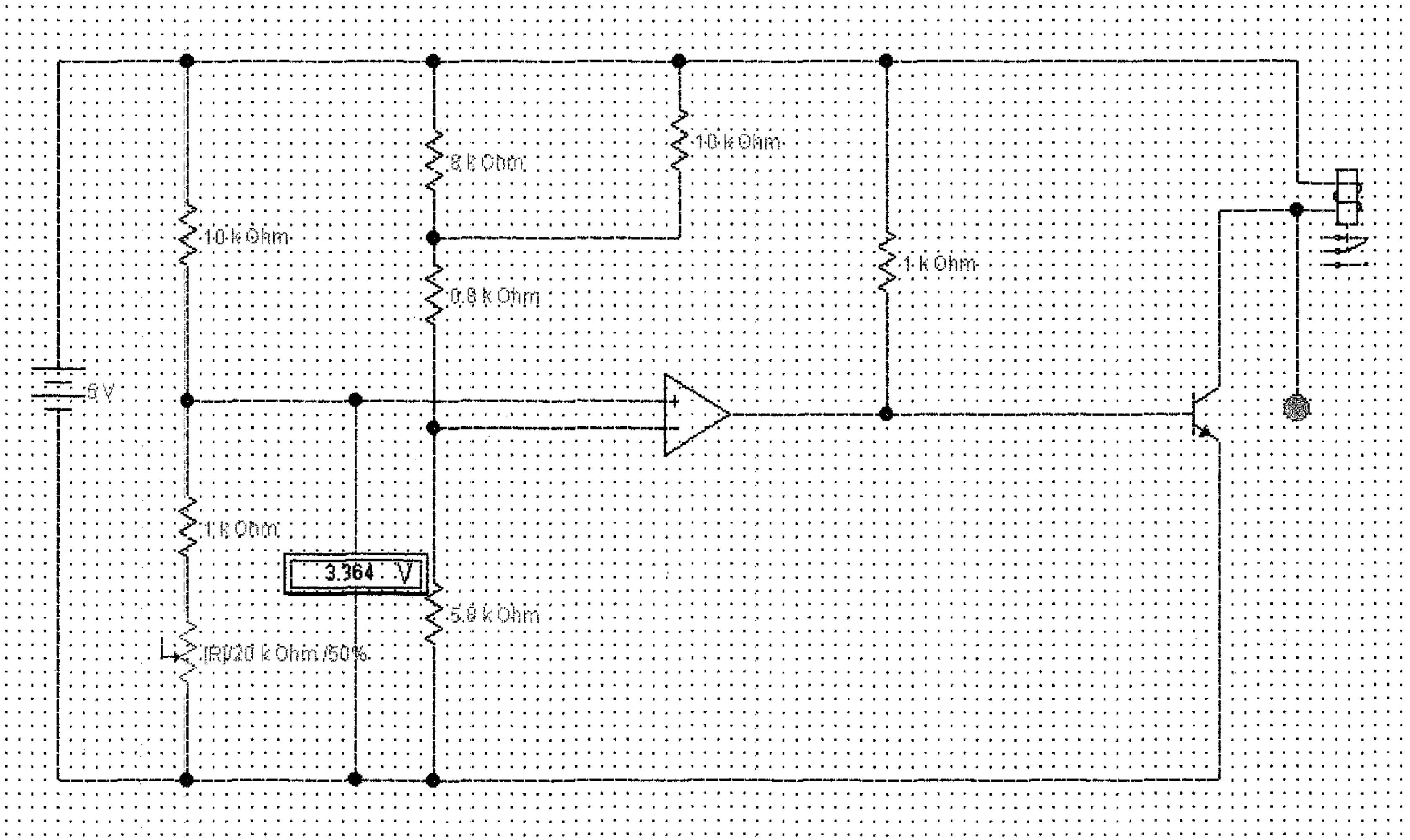

Figure 4.1: Simulation Circuit for MQ-6 Gas Sensor

From the results, it can be said that as the resistance of the load gets higher, the resistance of the sensor also increases. Figure 4.2 shows the corresponding values of sensor resistance to the load resistance.

4.3 Gas Sensor Operation

The operation is the MQ-6 is basically by a decrease in electrical resistance when gaseous butane/propane (LP-Gas) is absorbed on the sensor surface. In air the sensor has a given resistance which is measured indirectly as the voltage at the load R_L. In the presence of deoxidizing gas the resistance of the detector goes down and this voltage rise is detected. In fresh air the current passing through the sensor and R_L is steady. When the gas fumes come in contact with the sensor, its electrical resistance decreases and the current flows through the load (R_L). The voltage developed across the wiper of R_L, which is connected to the gate of MQ-6, triggers the MQ-6 into conduction.

Figure 4.2 shows the basic circuit for MQ-6. The variation in resistance of the sensor is measured indirectly as a change in voltage appearing across the load resistor R_L. However, when a combustible gas such as propane comes in contact with the sensor surface, the sensor resistance decreases in accordance with the gas concentration present.

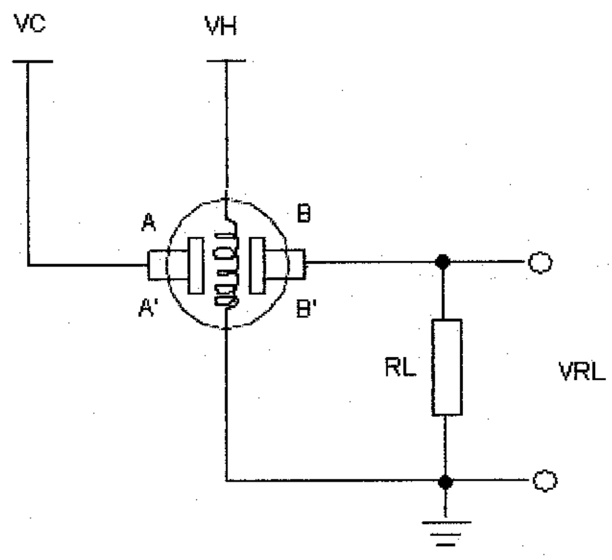

Figure 4.2: Basic Test Circuit

The voltage change across R_L is the same when V_C and V_H are supplied from AC or DC sources. When the output signal (V_{RL}) is measured, R_S (sensor resistance) is converted by Equation 4.1.

4.4 Gas Sensor Experiments

As mentioned before, the MQ-6 gas sensor is a resistive device, when it detects LP gas its resistance decreases. The voltage rise signifies the resistance drop in the sensor. One way to observe this is by using the PASCO and Data Studio software. However, due to time constraint, another way of obtaining the experimental values is by observing the changes in the voltage by using multimeter.

Before conducting the experiment, the connections of the circuit and sensor is checked. As can be seen in Figure 4.3, the heater pins, labeled as H on the MQ-6 gas sensor are already connected to an internal heater coil. However Pins A need to be connected externally since the legs are not internally linked. Same goes for Pins B.

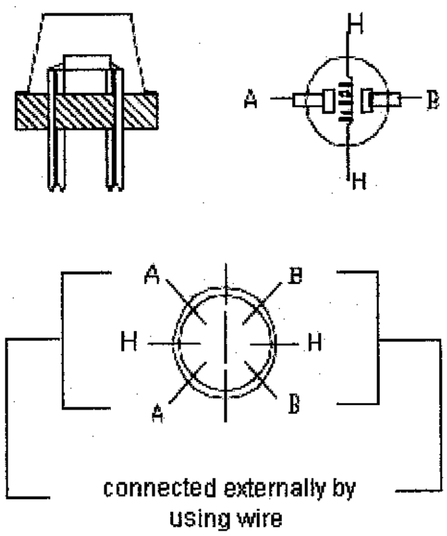

Figure 4.3: The MQ-6 Sensor pins connection

For the gas sensor, an initial 10-minutes warm-up period is required when it first turn on before conducting the experiment. The length of the warm up period will decrease with repeated use.

The results during preheating when exposed to LP Gas are as shown in Table 4.3. In Table 4.3 it can be seen that the load voltage is almost constant during the preheating time. The values indicate humidity or other foreign material that might also been sensed by the sensor is absorb by its surface.

Table 4.3: Voltage drop of sensor during preheating time(for 10 minutes)

Time (min)	V_L
1	0.017
2	0.016
3	0.015
4	0.015
5	0.015
6	0.015
7	0.015
8	0.015
9	0.015
10	0.014

Table 4.4 shows the different values of V_L when the sensor is exposed to LP-Gas. Several attempts were made to ensure that the sensor is operating accordingly. From the table, it can be seen that the sensor rapidly sense the changes in the concentration of LP Gas in air with minimum time taken to reach the maximum V_L is found to be 1.02 seconds. This shows that the sensor is very sensitive to the target gas.

Table 4.4: Voltage drop of sensor during exposure to LP gas

Attempt	V_L before exposure	Max V_L (during exposure)	Time taken to reach Max V_L (sec)
1	0.033	3.485	10.52
2	0.035	1.210	17.35
3	0.035	3.334	6.58
4	0.051	3.475	1.31
5	0.034	3.841	3.83
6	0.025	3.381	9.02
7	0.029	3.938	1.14
8	0.029	4.007	1.02

For Attempts 5 till 8 the time taken for the gas sensor to stabilizes back are also recorded.

Table 4.5: Voltage drop of sensor during stabilization

Attempt	Time taken to stabilize (sec)	V_L when sensor is stabilized
5	47.48	0.033
6	47.16	0.032
7	44.59	0.032
8	46.58	0.032

From these results, Equation 4.1 is again used to find the sensing resistance of the sensor in the real environment. Taking the maximum reading of V_L (4.007V) from the experiment, Rs is found to be 4956.33Ω.At minimum reading of V_L (1.21V), the Rs is found to be 62,644.63Ω.

All these values are obtained when the gas is exposed at a distance of about 0.5 cm from the sensor surface. At the distance of 15 cm, the maximum V_L observed is 4.48 V and it took about average of 16 seconds for the sensor to reach its max V_L. A few other attempts are taken to get the average value of V_L at this distance. The results are tabulated in Table 4.6.

Table 4.6: Voltage of sensor during exposure at 15 cm

Attempt	V_L during exposure
1	0.678
2	0.741
3	0.576
4	0.649
5	0.753

From this table, the average V_L is 0.6794 V. Using Equation 4.1, the R_S is equals to 127,189Ω, indicating that the concentration of LP gas is not too high if compared to the when exposed at distance of 0.5 cm.

Therefore, the closer the distance between the lighter (gas) and the sensor results in higher concentration of gas that is being exposed to the sensor. Higher V_L means larger concentration .Therefore, the time taken for the load voltage, V_L to reach the maximum during every exposure is less when the distance is near.

During the experiment, the sensor is hot since the heating still takes place while it is working. When some humidity is applied, the V_L tends to decreased below the stabilized value. The sensor circuit is constructed with all components in series (sensor and 20 kΩ resistor).

4.5 The Microcontroller

4.5.1 PIC16F877 Microcontroller

The program for the gas detector is blown in the PIC 16F877. A crystal clock is needed for the microcontroller to function once the chip has been programmed. For the microcontroller gas detector, there will be three outputs. First is the Red or Warning LED which when the gas concentration reaches alarm threshold, the LED lights up faintly and, after some time, lights up brightly. The second output is the buzzer which gives audible alarm when the gas concentration reaches beyond the LEL. The last output is the fan which moves to vent-out the gas when the gas concentration reaches far beyond the LEL. It is activated together with the LED and buzzer.

There would be one input which is the sensor circuit, creating a total 4 input/output pins and plus other pins that are used for the crystal clock, Vcc and ground. In this case the PIC 16F877 is suitable for this project.

The gas detector would operate most efficiently running under autonomous mode. Since the program necessary to produce the desired results needed for the gas detector is fairly straightforward the software was designed using PIC16F877 assembly. The gas sensor input will output an analog signal to the PIC that would have to be converted to a digital representation for the PIC to understand.

4.5.2 The Microcontroller Language

Microcontrollers are usually programmed using the assembly language. The language consists of various mnemonics which describe the instructions. An assembler language is unique to a microcontroller and the assembly language of a certain microcontroller can not be used for any other type of microcontroller. Although the assembly language is very fast, it has some major disadvantages.

Perhaps the most important disadvantage is that the assembly language can become very complex and difficult to maintain. It is usually a very time consuming task to develop large projects using the assembly language. However, since this project only requires the basic analog-to-digital output, the assembly language used is not too difficult to understand.

As mentioned before, microcontrollers can be programmed and compiled using the MPLab. This compiler generates native machine code which can directly be loaded into the memory of the target microcontroller. Figure 4.4 shows the environment of the MPLab.

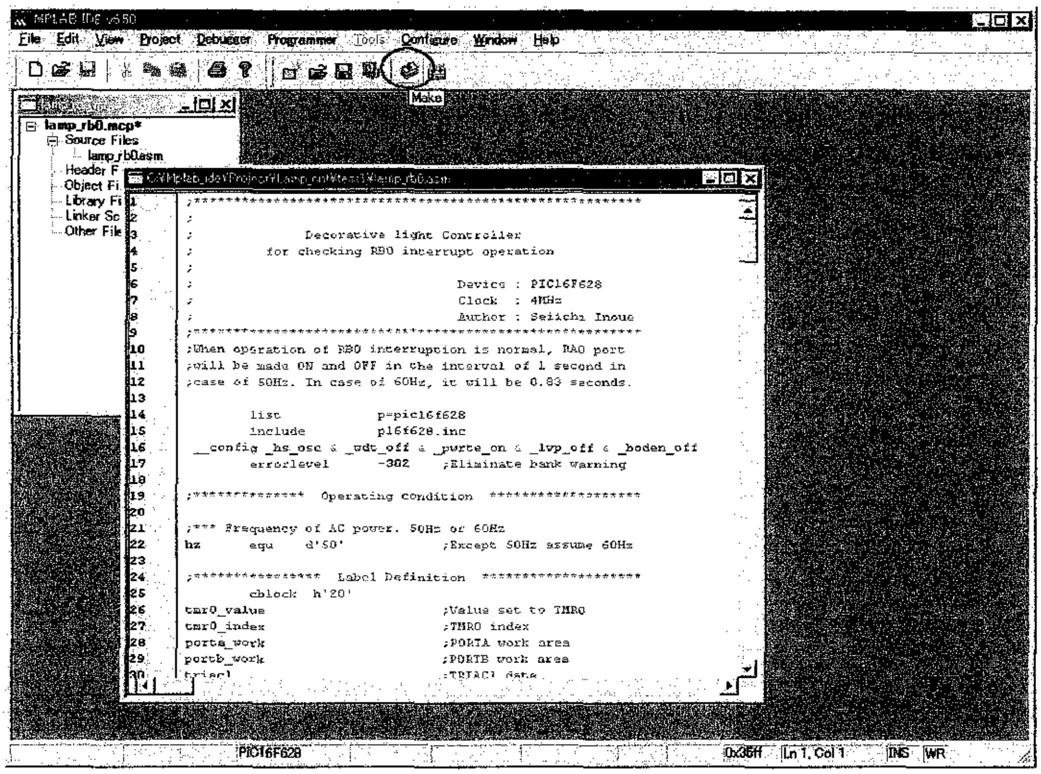

Figure 4.4 : MPLab Environment

4.5.3 Voltage Range and Resolution

The resolution of the converter chip can be obtained by taking the voltage range from REF- to REF+ and divide by 8-bit resolution (or 256). From the tabulated result (Table 4.4) it can be seen that the voltage that is to be read varies from 1to more than 4 V. Assuming that the voltage varies by 3v, say from 1 to 5 V, the REF- is set to 1 V and REF+ to 5 V.

Therefore, the voltage resolution = 5/256 = 0.0195 V. Thus, reading the number 100 from serial A/D converter (built-in inside the PIC 16F877) is equal to a voltage of 2.95 V [(100 x 0.0195 = 1.95V; 1.17 V + REF - (1 V) = 2.95 V. However, the A/D converter value can only be visualized if the LCD display is interfaced to the microcontroller circuit.

The sensor output voltage (V_L) will vary between 0 to less than 5 V. Because of the fast response of the sensor, it is hard to determine at which voltage the alarms will be triggered.

However, from the testing done, it can be assumed that the alarm starts to work when the voltage rises to almost 1 V. Therefore, VREF = 0.9V.

Table 4.7: Alarm conditions

Condition	Alarm type
VSENSE > VREF	Gas alarm level 1
VSENSE >> VREF	Gas alarm level 2
VSENSE close to 0	Sensor malfunction

4.5.4 Microcontroller Experiments

The testing of the software consisted of mainly using LEDs' for the outputs and using a power source for the inputs. This was a practical simulation of how the software should run, except an analog input was not used. The main strategy behind this was to test the PIC's ability to read in a voltage input and compare that input to a constant threshold. After the PIC compares the input it will decide to either turn on the LED or switch off the LED. In other words, if a voltage of 5V signal was input into the PIC input, the PIC will test that input and either switch on or off a light.

For the program, two experiments are conducted. Each experiment is conducted using two microcontrollers, PIC16F84A and PIC16F877. The program for microcontroller PIC 16F84A can be viewed in APPENDIX 2. The program works as follows. Port A of the microcontroller is set as the input, and Port B as the output. The input to the microcontroller is the voltage from the comparator of the gas sensor circuit. The voltage levels are as indicated in the Figure 4.5.

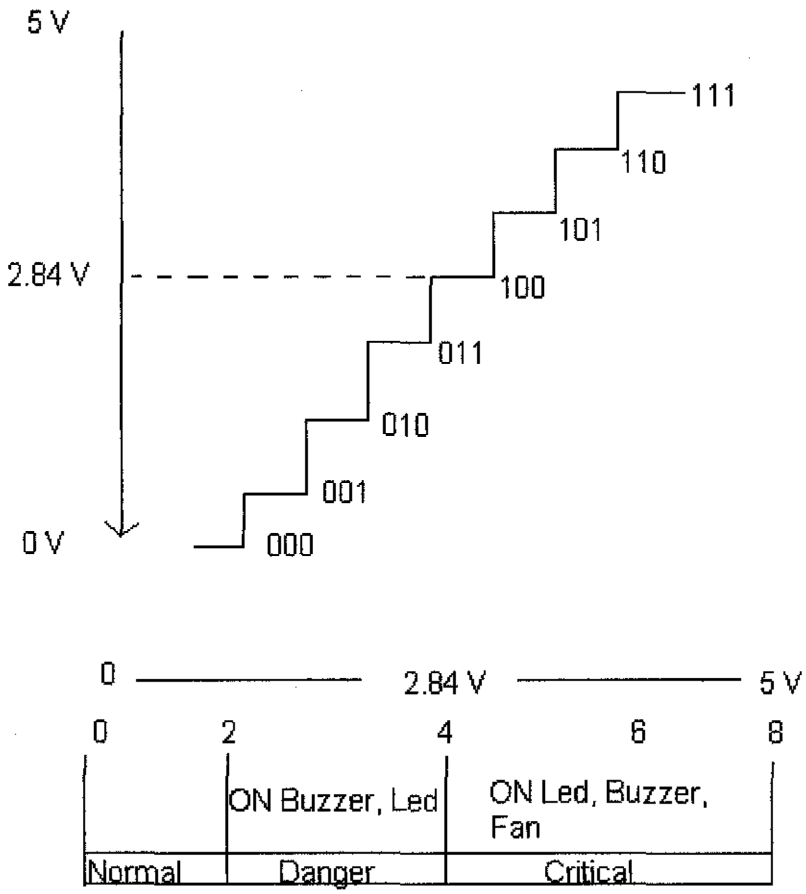

Figure 4.5: Voltage Levels of Gas Sensor

When the voltage is between 0 to 1.4 V the voltage range is considered normal where at this point, the fan, buzzer and the warning LED will not turn on. The voltage between these values indicates that the concentration of the gas is still within safe limits. If the voltage should rise between more than 1.4 V to 2.8 V, the voltage is considered high, which indicates the drop in the resistance values of the gas sensor. This shows that the concentration of the gas is dangerous, and the residents need to be alarmed of the increment in the gas concentration. Therefore, the buzzer will sound, and the warning led will turn on to alert the people around. When the gas reaches the range between 2.8 V to 5.0 V the fan will be actuated along with the buzzer and warning Led. The actuation of the fan will help to reduce the gas concentration to prevent any destruction. At this point the concentration is considered critical. If somehow the voltage input to the microcontroller is beyond 5.0 V the program will detect the error and will loop again to determine the appropriate output.

The program had been run and compiled successfully and has been burn onto the PIC16F84A. However, during testing with all the detector circuits interfaced to the microcontroller, the output did not produce the response. Thus, another program is constructed and this time using the PIC 16F877 microcontroller.

The code for this program can be viewed in APPENDIX 3. The working is similar as the previous program only that the analog input is readily converted to digital in the microcontroller. After running the test using this program for the detector circuit, it produce the wanted outputs and in appropriate sequence too. Thus, the program is considered successful. The program flowchart can is as in Figure 4.7.

4.6 Detector Circuit Implementation

Figure 4.6 shows the whole detector circuit that has been constructed. The LEDS (labeled as 1 till 8) are put to indicate the rise of voltage coming from the sensor circuit. A miniature voltage regulator circuit is put to regulate the voltage from AC supply from 9V to 5V. The regulated voltage will be used to power up the sensor and microcontroller circuit. The output of the sensor circuit will be the input for the microcontroller at Pin 3. The outputs of the microcontroller come from Pins 15, 16, 17, 18, 23, 24, 25 and 26. The circuit for the detector outputs; the warning LED, buzzer and fan are tapped from outputs of Pins 17, 23 and 26.

As the voltage goes higher (higher gas concentration), the outputs will be triggered into conduction in a sequence as indicated in the flowchart in Figure 4.7. The buzzer used is cheap and inexpensive. It was found that no external circuitry was needed as it can be hooked up directly to the PIC output. The fan motor could not be hooked directly to an output pin on the PIC as noticed after trying to do so. The fan needs to be powered up by external DC supply of 12 V in order to actuate it. The output of the microcontroller would only energize the 6V relay to signal that the fan needs to be activated.

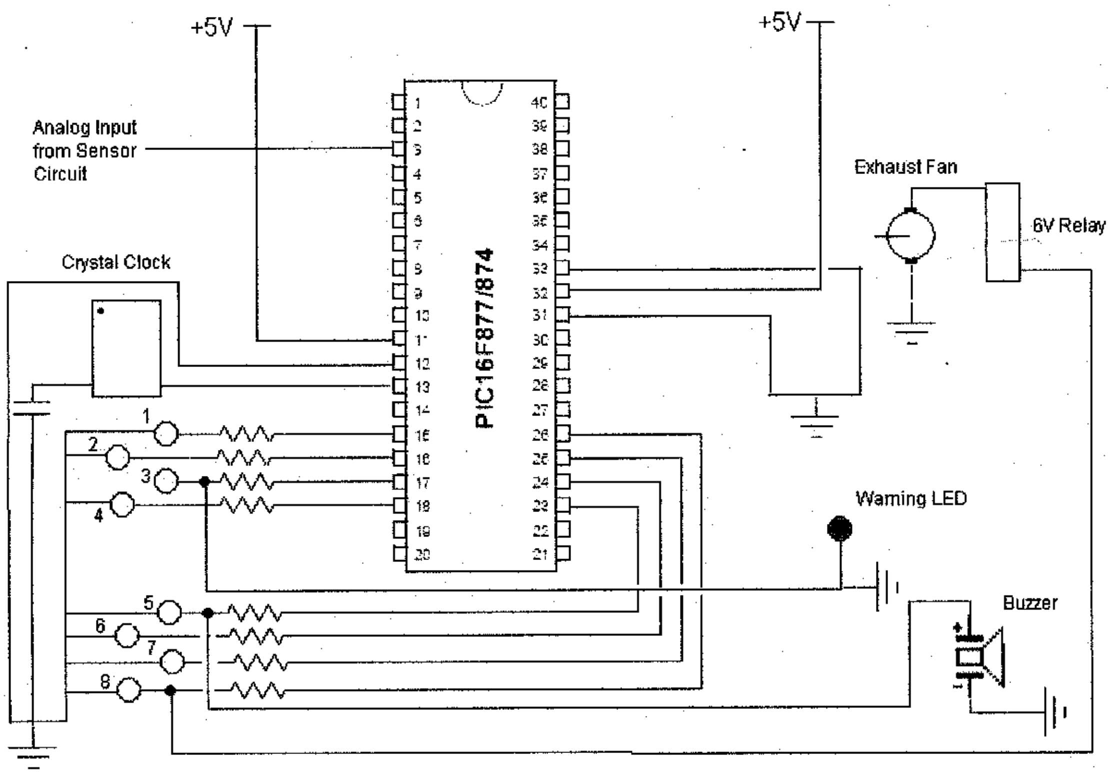

Figure 4.6: The Microcontroller- based LP-Gas Detector Schematic

PROGRAM FLOWCHART

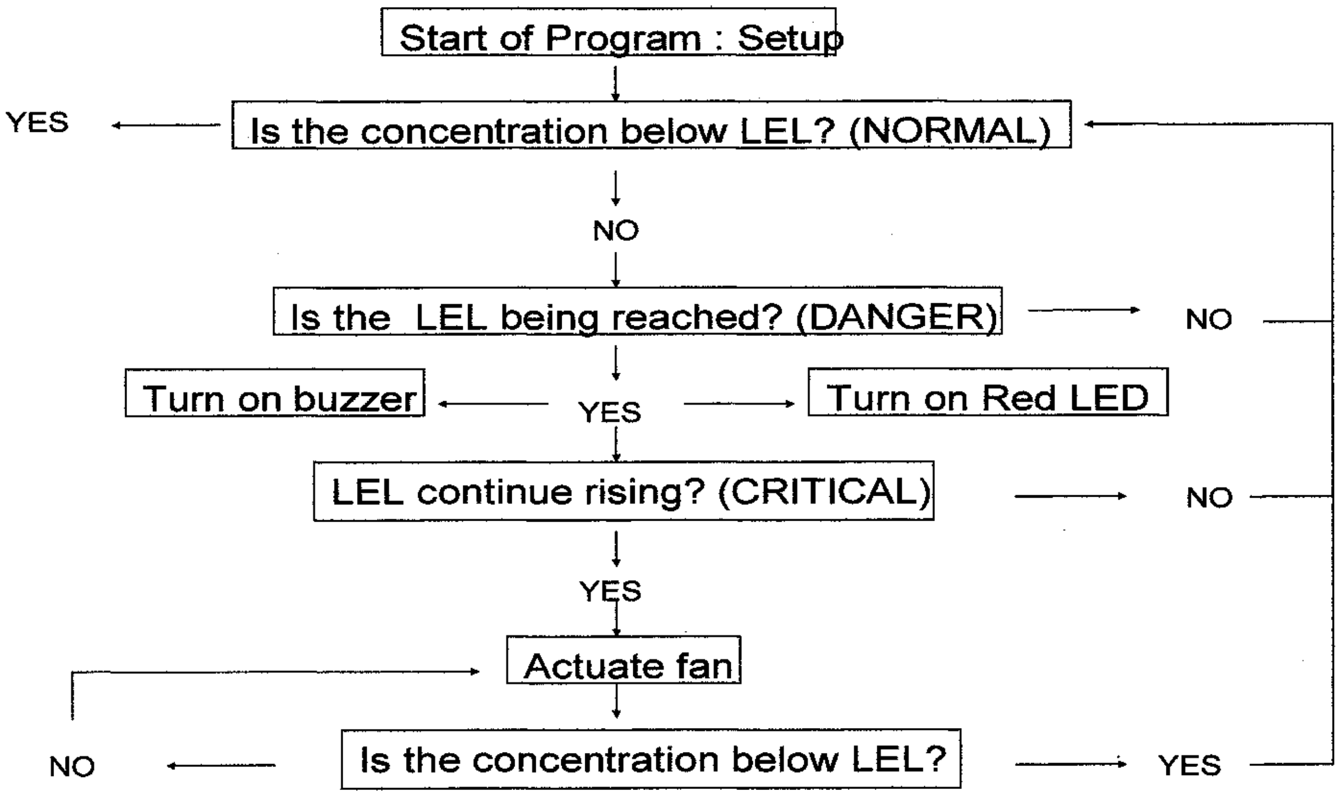

Figure 4.7: Microcontroller Program Flowchart

4.7 Cost Estimation

The cost below is the price for a physical unit of a gas detector

Table 4.8: Components Price Listings

Components	Quantity (Unit)	Cost (RM)
MQ-6 Gas Sensor	1	50.00
PIC 16F877	1	30.00
Buzzer	1	2.50
Fan	1	10.00
LED	10	6.00
Capacitors	4	4.00
Relay	1	6.00
Veraboard	3	3.60
AC Supply Adapter	1	25.00
Total Estimation		**137.10**

The total estimation is based on assumptions of the cost of each component. The actual cost could be less than RM100. The cost for the software, MPLab is not included since it can be downloaded for free from the internet. The burner can also be built and normally the cost will not exceed RM20.

From this cost estimation, it can be concluded that the microcontroller-based gas detector is low in price and can be obtained for much cheaper price if it were to be sold in large numbers.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The project aim was to construct a gas detector unit which monitors the level of LP Gas in air of a confined space or a chamber. Consequently, this intend is successfully realized. From the development of the project, it can be concluded that the use of MQ-6 sensor together with the microcontroller produces a reliable gas detector unit. The presence of the LP gas is indicated by the decrease of the sensor resistance. From the simulations done, the results obtained verified that the circuit responds to the presence of LP-Gas. Even without the comparator (which was initially used in the simulation), the detector unit still work successfully because of the miraculous microcontroller, which controls the outputs of the detector.

From the experiments carried out, it can be summarized that the gas detector was able to detect the presence of gas assuming the gas is absorb directly on the sensor surface. The gas detector was able to detect high LPG concentration and produce fast response.

Together with low cost and good quality gas sensor, the detector unit is also possible to be developed in really short time. The reproducibility is great and the detector can be assembled and debugged also by electronic beginner.

The gas detector itself is very good guard which increases the safety of your home. It helps to prevent dangerous situations when the gas cooker or gas boiler have uncontrolled leakage

5.2 Future Recommendations

For improving this design, a few recommendations are proposed. For future construction, the circuit can be transferred to the Printed Circuit Board (PCB) for much neat and stable performance. For better monitoring of the voltage levels, Liquid Crystal Display (LCD) display can be interfaced to the microcontroller. Other type of gas sensor can also be incorporated to replace the MQ-6. The type of sensor which is commonly used is the TGS sensor (LPM2610). The datasheet is as in APPENDIX 9. However, the design will be better and less power consuming if new sensor that need not be heated are found. This will save time and ensure that the sensor works perfectly once supplied with specific voltage. The gas detector in the end can also be combined with any central home security system and can be also connected to some wireless transmitter.

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APPENDICES

APPENDIX 1

Table 10: The familiar combustible, liquid gas explosion limits

Gas name	Explosion limit(%)		Gas proportion (air=1)	Sparking point	toxicity	Permission concentration
	Lower limit	Upper lim				
Methane	5	15	0.55	537.8	asphyxiation	
Ethane	3	12.5	1.406	515	asphyxiation	
Propane	**2.3**	**9.15**	**1.56**	**467.8**	**asphyxiation**	**1000ppm**
Butane	**1.8**	**8.44**	**2**		**asphyxiation**	
Ethene	2.7	28.5			narcosis	
Propylene	2.4	11			narcosis	
Acetylene	1.5	82	0.906	305		
Hydrogen	4.1	74.2	0.069	585	asphyxiation	
CO	12.5	75.6	0.967	608	toxicosis	50ppm
Natural gases	5	15	<1		asphyxiation	
LPG	**3**		**>1**		**asphyxiation**	
City gas	4	30	0.4		toxicosis	100ppm
Gasoline	1.2	7.5	3.3	280	Asphyxiation& asphyxiation	
Coal oil	0.7	5	4~5			
Alcohol	3.3	19	1.58	392		1000ppm
Ethanol	3.5	6.7	0.78	422		1mg/m
Methyl Alcohol	6.7	36	0.79	385		0.05mg/m
Acetone	8.1	13	0.79			1000ppm

APPENDIX 2

APPENDIX 2

PIC 16F84A Program

```
#include <P16F84A.inc>


;---------Reserving register------------
cblock    0x0C

endc
;---------------------------------------

;----------Equating Variable--------
Fan       equ     3
Buzzer    equ     4
Led       equ     5
;----------------------------------



          org     0x00
          goto    setup

setup     bsf     STATUS, RP0         ; select bank 1
          movlw   0xFF                ;
          movwf   TRISA               ; set PortA as an input
          movlw   0x07                ; set PortB Pin 3-7 as an output
          movwf   TRISB               ; move to control register of port b
          bcf     STATUS, RP0         ; select bank 0
          bsf     PORTB, 7            ; Pull PortB, P7 HIGH
          goto    main

main      clrwdt                      ; Clear content of watch dog timer
          nop                         ; so that it will never overflow
          call    Chk_Input ; Check input from PortA
          goto    main                ; Goto main and keep checking input from PortA



Chk_Input         nop

TryNormal         clrwdt
                  movf    PORTA, w            ; read from Port B
                  addlw   d'255' - d'2'       ; if the value is 2 and less
                  btfsc   STATUS, C           ; check whether overflow occur
                  goto    TryDanger; goto TryDanger if overflow occur
                                              ; if overflow does not occur
                  bcf     PORTB, Fan          ; Fan is switched OFF
                  bcf     PORTB, Buzzer       ; Buzzer is switched OFF
                  bcf     PORTB, Led          ; Led is switched OFF
                  return

TryDanger         clrwdt
                  movf    PORTA, w            ; read from Port B
                  addlw   d'255' - d'4'       ; if the value is 4 and less
                  btfsc   STATUS, C           ; check whether overflow occur
                  goto    TryCritical; goto TryCritical if overflow occur
                                              ; if overflow does not occur
                  bcf     PORTB, Fan          ; Fan is switched OFF
                  bsf     PORTB, Buzzer       ; Buzzer is switched ON
                  bsf     PORTB, Led          ; Led is switched ON
                  return

TryCritical       clrwdt
                  movf    PORTA, w            ; read from Port B
```

```
sublw   d'255' - d'8'           ; if the value is 8 and less

                btfsc   STATUS, C       ; check whether overflow occur
                goto    TryError        ; goto TryError to indicate the value is not valid
                                        ; if overflow occur
                bsf     PORTB, Fan      ; Fan is switched ON
                bsf     PORTB, Buzzer   ; Buzzer is switched ON
                bsf     PORTB, Led      ; Led is switched ON
                return

TryError nop                            ;
                bcf     PORTB, 7        ; ON Error Led
_TryError       nop                             ; Looping until microcontroller
                goto    _TryError ; reset itself

end
```

APPENDIX 3

APPENDIX 3

PIC 16F877 Program

```
#include <p16f877.inc>

                    cblock      0x20        ;start of general purpose registers
                    NumL
                    NumH
                    endc

;start of program

                    ORG                     0x0000
                    GOTO                    Initialise
                    ORG                     0x0004


Initialise  clrf    PORTA
                    clrf                    PORTB
                    clrf                    PORTC
                    BANKSEL                 ADCON1                  ;disable A2D
                    movlw                   0x06
                    movwf                   ADCON1
                    BANKSEL                 PORTA


SetPorts    bcf             STATUS, RP0             ;select bank 0
            call                    Init_ADC0               ;initialise analogue input
            bsf                     STATUS,RP0              ;bank 1
            bcf                     STATUS,RP1
            movlw   H'00'
            movwf   TRISC                           ;set as output
            movlw   H'FF'
            movwf   TRISB                           ;set as input
            bcf                     STATUS, RP0

Main
            btfsc   PORTB,0
            call                    Temp
            btfss   PORTB,0
            call                    Speed
            goto                    Main


Init_ADC0                                           ;set for AN0
                                                    ; Set ADCON0
            movlw   b'01000001;select porta,pin 0
            movwf                   ADCON0  ; Set ADCON1
            BANKSEL                 ADCON1
            movlw                   b'00000000' ;enable a/d
            movwf                   ADCON1
            BANKSEL                 ADCON0
            Return


Init_ADC1                                           ;set for AN1
                                                    ; Set ADCON0
            movlw                   b'01001001';select port a, pin 1
            movwf                   ADCON0  ; Set ADCON1
            BANKSEL                 ADCON1
            movlw                   b'00000000'     ;enable a/d
```

APPENDIX 3

```
movwf           ADCON1
                BANKSEL         ADCON0
                Return


Read_ADC
                bsf             ADCON0, GO_DONE         ;initiate  conversion
                btfsc     ADCON0, GO_DONE
                goto      $-1                   ;wait for ADC to finish
                movf            ADRESH,W
        movwf             PORTC
                return


Read_ADC2
                bsf                           ADCON0,GO_DONE;initiate conversion
                btfsc     ADCON0, GO_DONE
                goto      $-1                   ;wait for ADC to finish
                movf            ADRESH,W
                movwf           PORTC
                return

Temp            call Init_ADC0
                call Read_ADC
                return

Speed           Call Init_ADC1
                Call Read_ADC2
                return

                end
```

APPENDIX 4

Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	SW	EW
TASK 1																
Selection of Project Topic																
Propose topic	■	■														
Topic assigned to student		●														
Preliminary Research Work																
Introduction		■	■													
Objective and scope			■	■												
Project planning			■	■												
List of references/literature				■												
Submission of Preliminary Report				●												
TASK 2																
Literature research			■	■	■	■	■									
Research on gas sensor and microcontroller				■	■	■	■	■								
Conceptual design (circuit schematic)						■	■	■	■	■						
Simulation & modification							■	■	■	■	■	■				
Submission of Progress Report									●							
TASK 3																
Modification & components purchasing								■	■	■	■	■				
Bread-boarding and testing										■	■	■	■			
Prepare Interim report									■	■	■	■				
Submission of Interim Report (Draft)													●			
Oral Presentation														■	■	
Submission of Interim Report																●

Gantt chart (Semester 2) of the Microcontroller-based LP-Gas Detector Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Project Work Continue		■	■														
	-Practical/Laboratory Work (Testing the circuit, PASCO)																	
2	Submission of Progress Report 1				●													
3	Project Work Continue				■	■	■	■										
	(PIC Programming, Troubleshooting the circuit)																	
4	Submission of Progress Report 2								●									
5	Project work continue								■	■	■	■	■					
	(Building the environment for the gas detector, PIC programming adjustments, interfacing the PIC with the sensor circuit)																	
6	Submission of Dissertation Final Draft													●				
7	Oral Presentation															●		
8	Submission of Project Dissertation																	●

● Milestone

■ Process

APPENDIX 5

APPENDIX 5

<u>Photos Taken during Experiments</u>

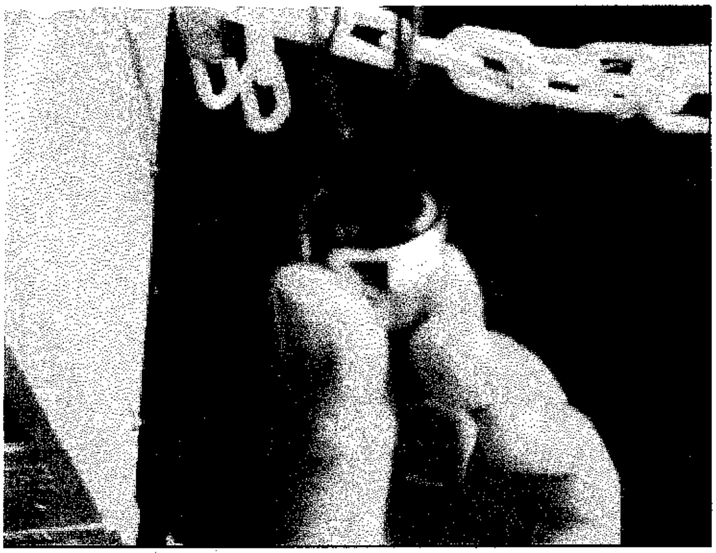


Figure I: The MQ-6 Sensor pins connection

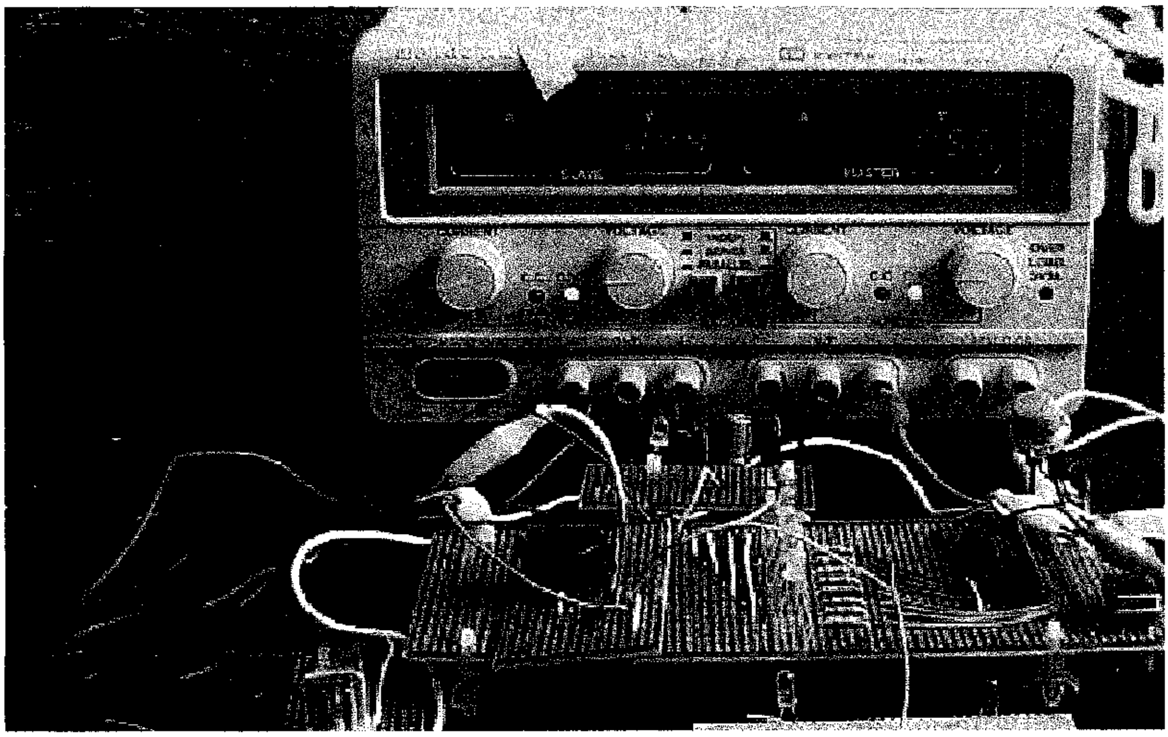
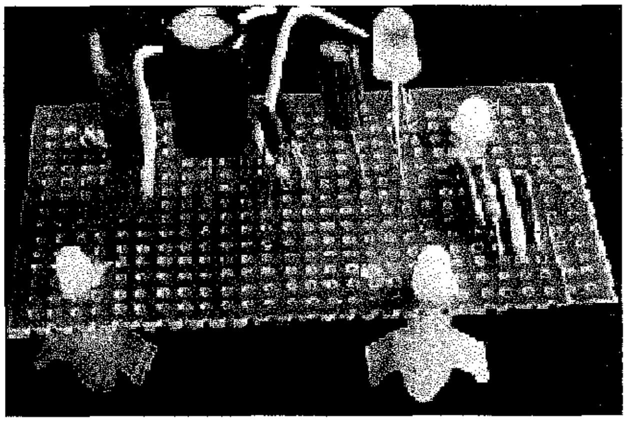
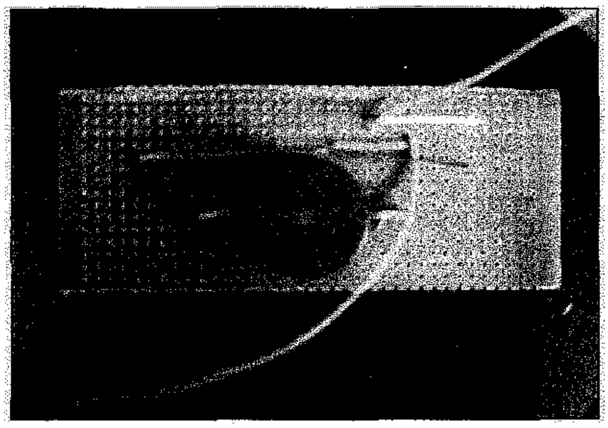


Figure II: Microcontroller-based LPG Detector Circuit

Figure III: Voltage-regulator Circuit





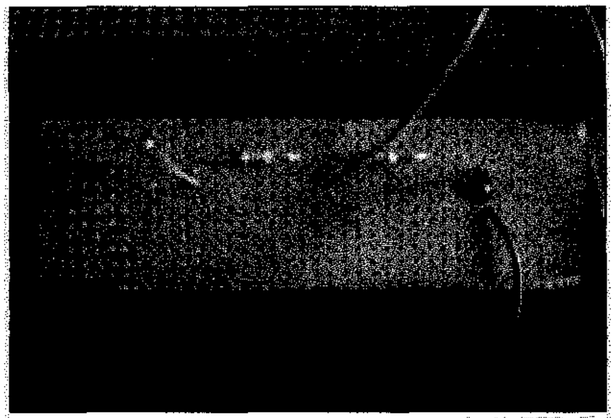


Figure IV: Buzzer Circuit

Figure VI: LED Circuit

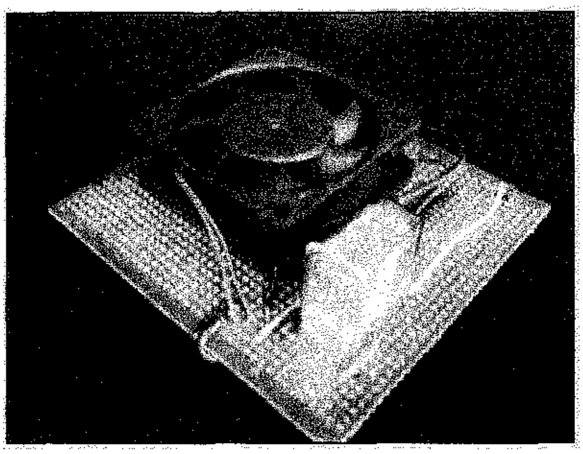


Figure V: Exhaust Fan Circuit

APPENDIX 6

Kitchen Environment with Gas Detector

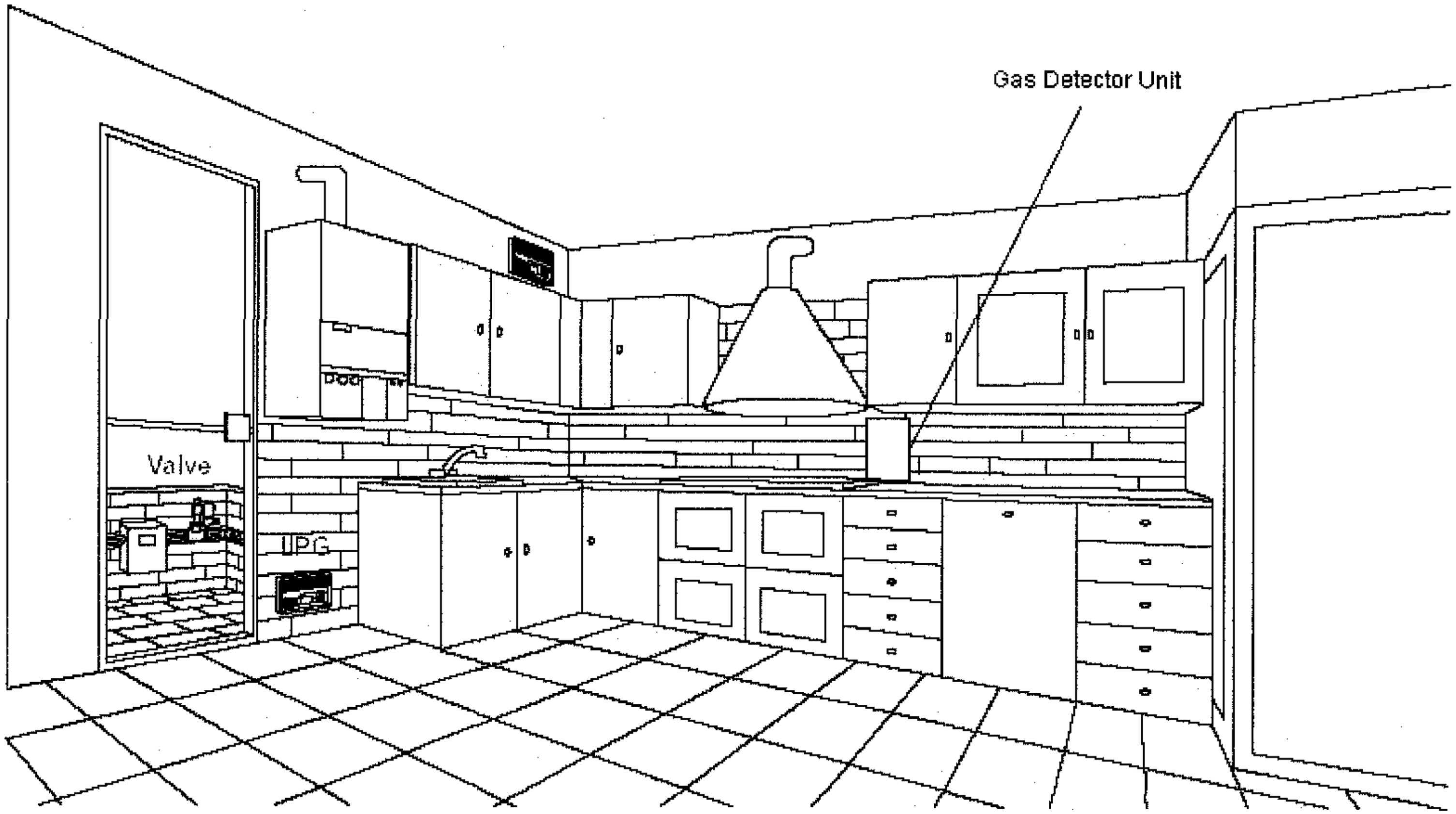


Figure VI: Kitchen Environment

Note that the gas detector is put near the cooking fumes to ensure the safety of the household. This detector is powered by the mains supply. It can be left switched on for hours to make sure that the level of LP Gas does not exceeds its limit.

APPENDIX 7

MICROCHIP

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

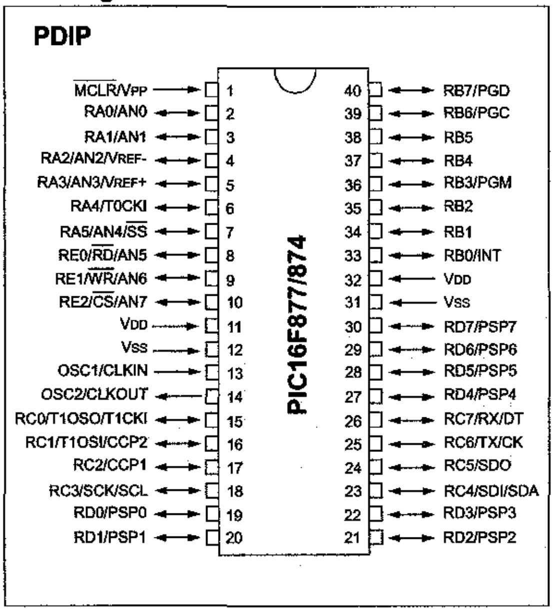
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- 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 368 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 (PWRT) 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 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 μA typical @ 3V, 32 kHz
  - < 1 μA typical standby current

Pin Diagram



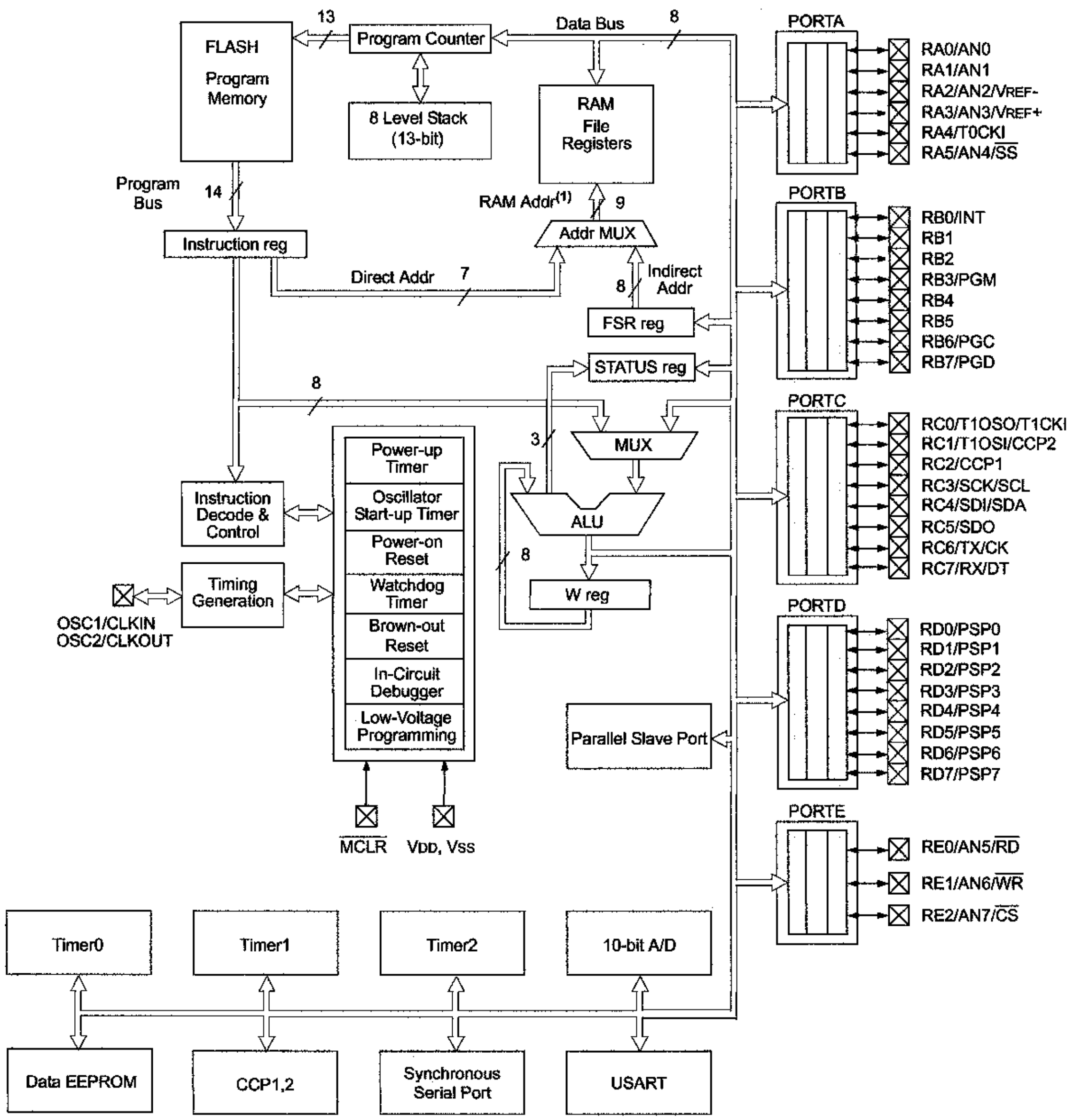
Peripheral Features:

- 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)

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	368	368
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	3	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	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

FIGURE 1-2: PIC16F874 AND PIC16F877 BLOCK DIAGRAM

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F874	4K	192 Bytes	128 Bytes
PIC16F877	8K	368 Bytes	256 Bytes



Note 1: Higher order bits are from the STATUS register.

1.0 DEVICE OVERVIEW

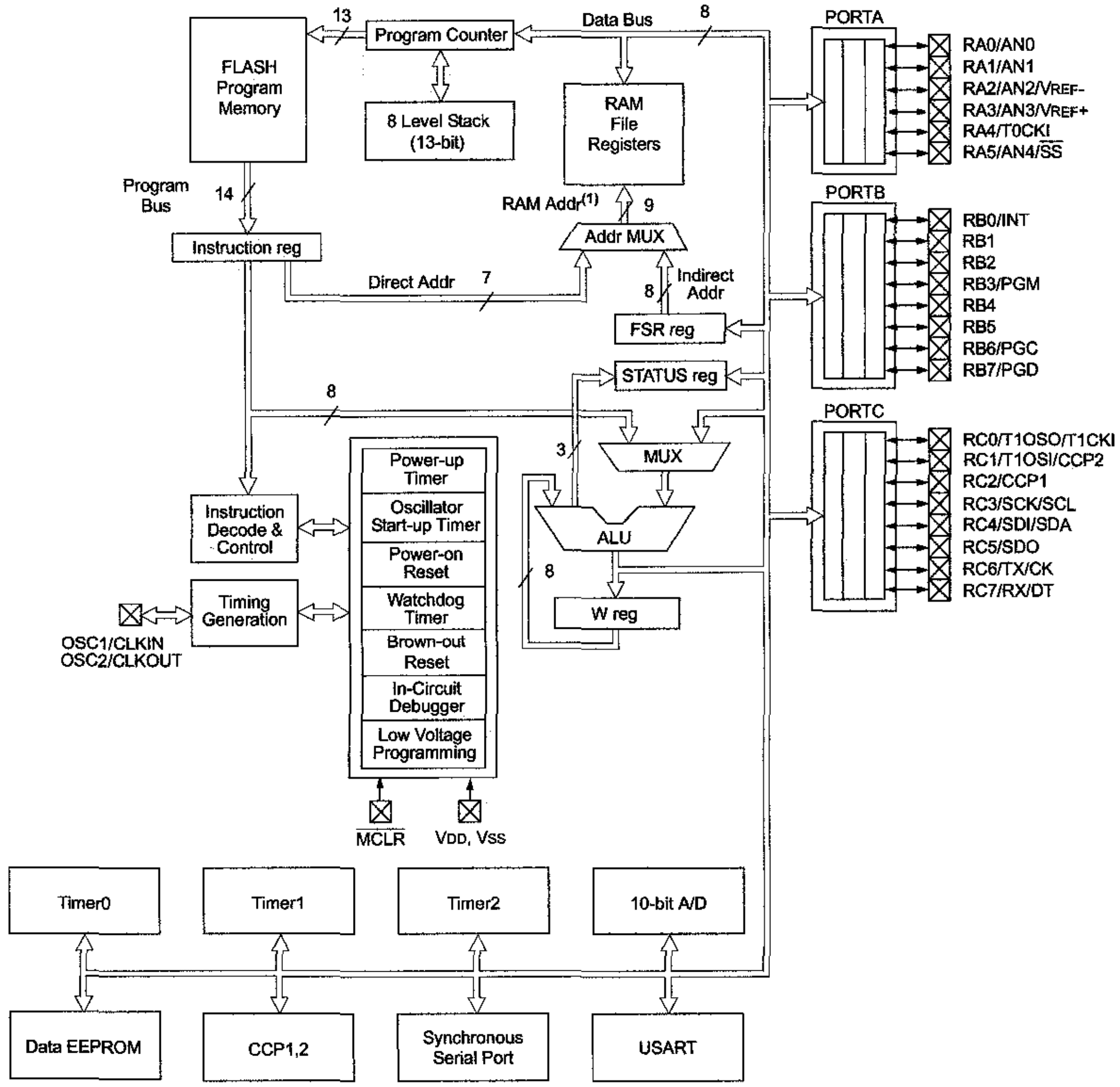
This document contains device specific information. Additional information may be found in the PICmicro™ Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip website. The Reference Manual should be considered a complementary document to this data sheet, and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

There are four devices (PIC16F873, PIC16F874, PIC16F876 and PIC16F877) covered by this data sheet. The PIC16F876/873 devices come in 28-pin packages and the PIC16F877/874 devices come in 40-pin packages. The Parallel Slave Port is not implemented on the 28-pin devices.

The following device block diagrams are sorted by pin number; 28-pin for Figure 1-1 and 40-pin for Figure 1-2. The 28-pin and 40-pin pinouts are listed in Table 1-1 and Table 1-2, respectively.

FIGURE 1-1: PIC16F873 AND PIC16F876 BLOCK DIAGRAM

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F873	4K	192 Bytes	128 Bytes
PIC16F876	8K	368 Bytes	256 Bytes



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1.0 DEVICE OVERVIEW

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FIGURE 1-1: PIC16F873 AND PIC16F876 BLOCK DIAGRAM

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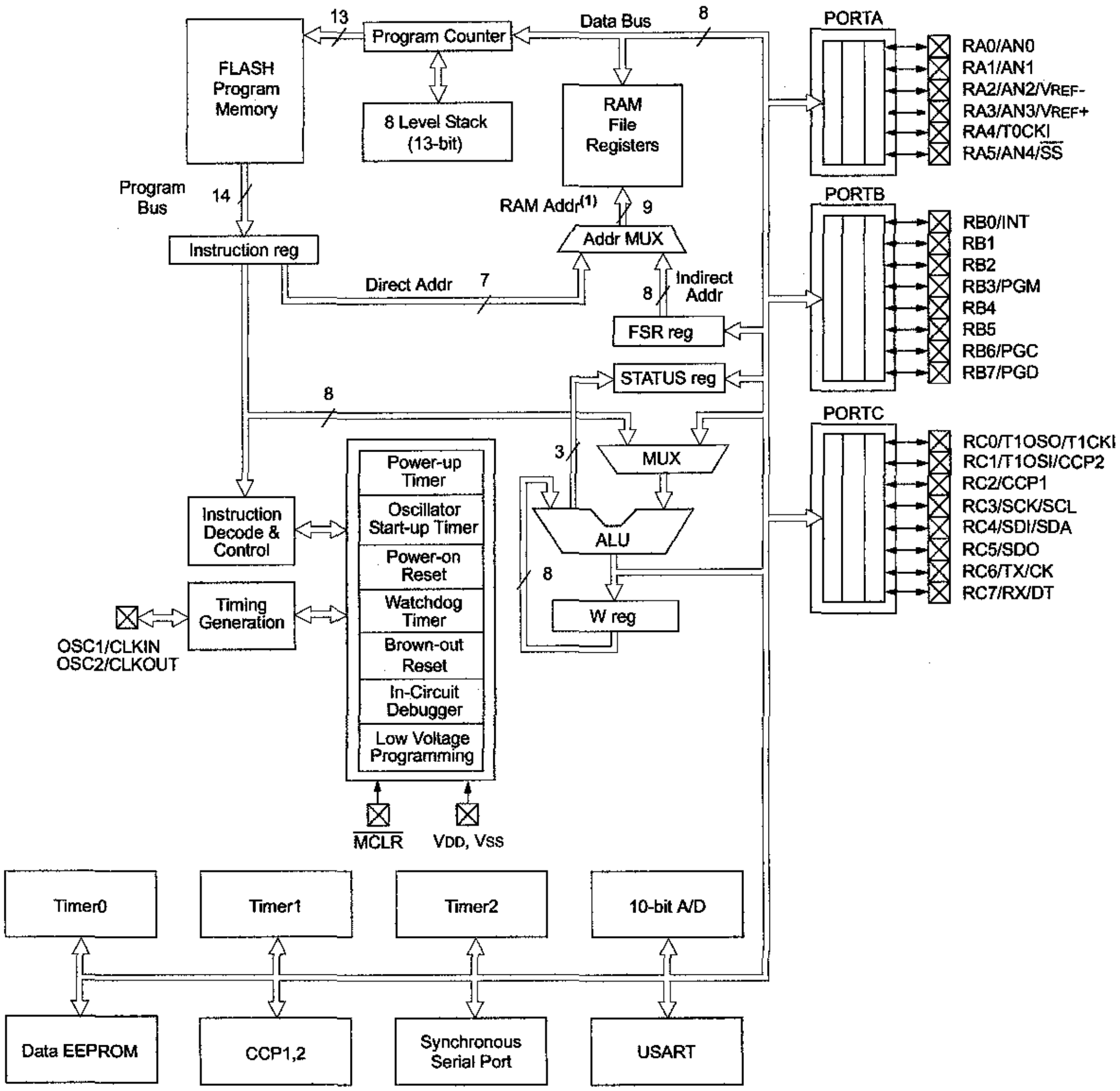


Note 1: Higher order bits are from the STATUS register.

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	2	18	I/P	ST	Master Clear (Reset) input or programming voltage input. This pin is an active low RESET to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1.
RA2/AN2/VREF-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
RA3/AN3/VREF+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/ counter. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL	
RB2	35	38	10	I/O	TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input.
RB4	37	41	14	I/O	TTL	Interrupt-on-change pin.
RB5	38	42	15	I/O	TTL	Interrupt-on-change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION (CONTINUED)

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/ output for both SPI and I^2C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	I/O	ST/TTL(3)	
RD1/PSP1	20	22	39	I/O	ST/TTL(3)	
RD2/PSP2	21	23	40	I/O	ST/TTL(3)	
RD3/PSP3	22	24	41	I/O	ST/TTL(3)	
RD4/PSP4	27	30	2	I/O	ST/TTL(3)	
RD5/PSP5	28	31	3	I/O	ST/TTL(3)	
RD6/PSP6	29	32	4	I/O	ST/TTL(3)	
RD7/PSP7	30	33	5	I/O	ST/TTL(3)	
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	I/O	ST/TTL(3)	RE0 can also be read control for the parallel slave port, or analog input5.
RE1/$\overline{WR}$/AN6	9	10	26	I/O	ST/TTL(3)	RE1 can also be write control for the parallel slave port, or analog input6.
RE2/$\overline{CS}$/AN7	10	11	27	I/O	ST/TTL(3)	RE2 can also be select control for the parallel slave port, or analog input7.
VSS	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
VDD	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28, 40	12,13, 33,34		—	These pins are not internally connected. These pins should be left unconnected.

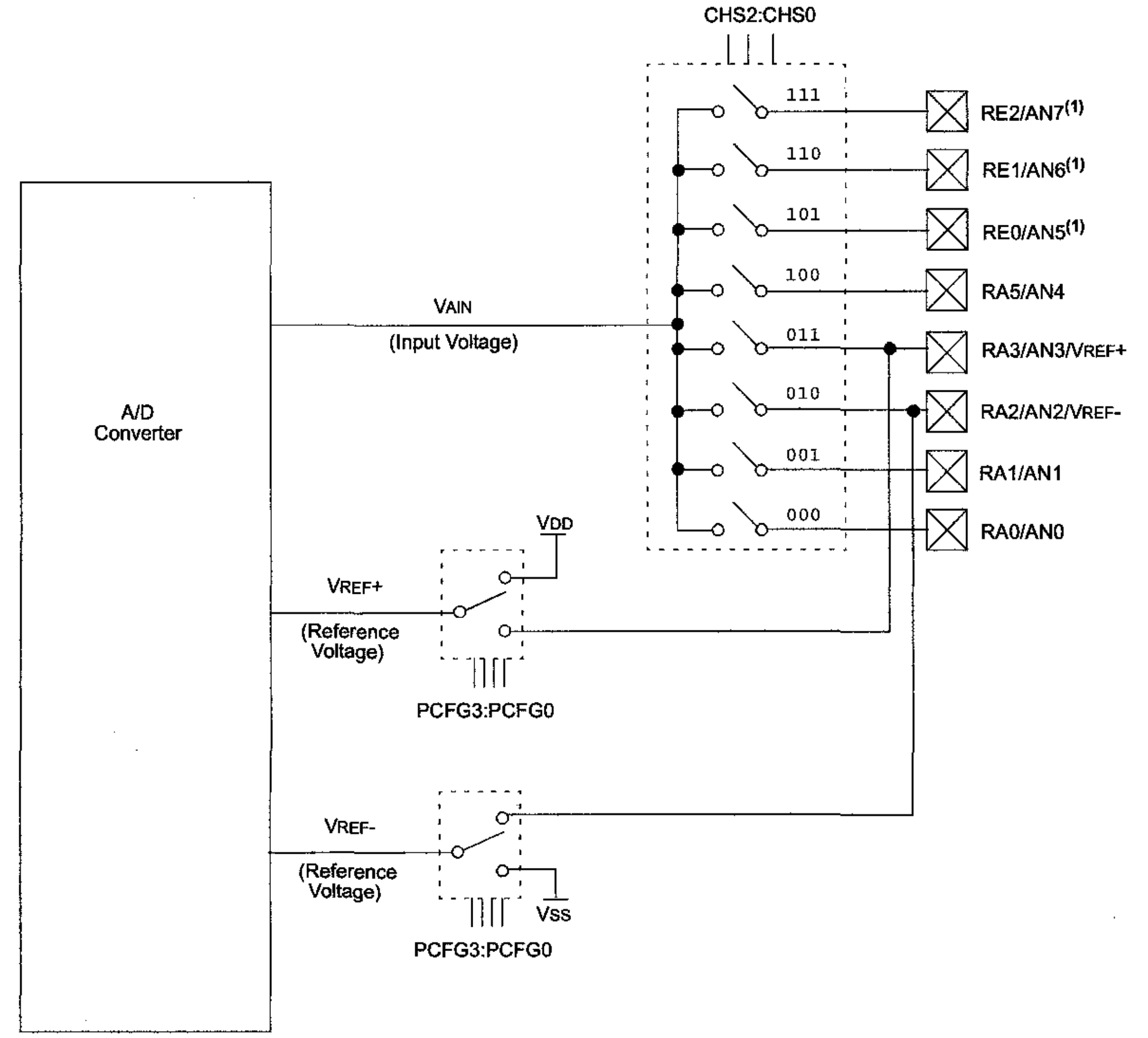
Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

These steps should be followed for doing an A/D Conversion:

1. Configure the A/D module:
   - Configure analog pins/voltage reference and digital I/O (ADCON1)
   - Select A/D input channel (ADCON0)
   - Select A/D conversion clock (ADCON0)
   - Turn on A/D module (ADCON0)
2. Configure A/D interrupt (if desired):
   - Clear ADIF bit
   - Set ADIE bit
   - Set PEIE bit
   - Set GIE bit
3. Wait the required acquisition time.
4. Start conversion:
   - Set GO/$\overline{\text{DONE}}$ bit (ADCON0)
5. Wait for A/D conversion to complete, by either:
   - Polling for the GO/$\overline{\text{DONE}}$ bit to be cleared (with interrupts enabled); OR
   - Waiting for the A/D interrupt
6. Read A/D result register pair (ADRESH:ADRESL), clear bit ADIF if required.
7. For the next conversion, go to step 1 or step 2, as required. The A/D conversion time per bit is defined as TAD. A minimum wait of 2TAD is required before the next acquisition starts.

FIGURE 11-1: A/D BLOCK DIAGRAM



Note 1: Not available on PIC16F873/876 devices.

REGISTER 11-2: ADCON1 REGISTER (ADDRESS 9Fh)

U-0	U-0	R/W-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
ADFM	—	—	—	PCFG3	PCFG2	PCFG1	PCFG0
bit 7							bit 0

bit 7 **ADFM:** A/D Result Format Select bit
1 = Right justified. 6 Most Significant bits of ADRESH are read as '0'.
0 = Left justified. 6 Least Significant bits of ADRESL are read as '0'.

bit 6-4 **Unimplemented:** Read as '0'

bit 3-0 **PCFG3:PCFG0**: A/D Port Configuration Control bits:

PCFG3: PCFG0	AN7(1) RE2	AN6(1) RE1	AN5(1) RE0	AN4 RA5	AN3 RA3	AN2 RA2	AN1 RA1	AN0 RA0	VREF+	VREF-	CHAN/ Refs(2)
0000	A	A	A	A	A	A	A	A	VDD	VSS	8/0
0001	A	A	A	A	VREF+	A	A	A	RA3	VSS	7/1
0010	D	D	D	A	A	A	A	A	VDD	VSS	5/0
0011	D	D	D	A	VREF+	A	A	A	RA3	VSS	4/1
0100	D	D	D	D	A	D	A	A	VDD	VSS	3/0
0101	D	D	D	D	VREF+	D	A	A	RA3	VSS	2/1
011x	D	D	D	D	D	D	D	D	VDD	VSS	0/0
1000	A	A	A	A	VREF+	VREF-	A	A	RA3	RA2	6/2
1001	D	D	A	A	A	A	A	A	VDD	VSS	6/0
1010	D	D	A	A	VREF+	A	A	A	RA3	VSS	5/1
1011	D	D	A	A	VREF+	VREF-	A	A	RA3	RA2	4/2
1100	D	D	D	A	VREF+	VREF-	A	A	RA3	RA2	3/2
1101	D	D	D	D	VREF+	VREF-	A	A	RA3	RA2	2/2
1110	D	D	D	D	D	D	D	A	VDD	VSS	1/0
1111	D	D	D	D	VREF+	VREF-	D	A	RA3	RA2	1/2

A = Analog input D = Digital I/O

Note 1: These channels are not available on PIC16F873/876 devices.
2: This column indicates the number of analog channels available as A/D inputs and the number of analog channels used as voltage reference inputs.

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

The ADRESH:ADRESL registers contain the 10-bit result of the A/D conversion. When the A/D conversion is complete, the result is loaded into this A/D result register pair, the GO/$\overline{\text{DONE}}$ bit (ADCON0<2>) is cleared and the A/D interrupt flag bit ADIF is set. The block diagram of the A/D module is shown in Figure 11-1.

After the A/D module has been configured as desired, the selected channel must be acquired before the conversion is started. The analog input channels must have their corresponding TRIS bits selected as inputs.

To determine sample time, see Section 11.1. After this acquisition time has elapsed, the A/D conversion can be started.

11.0 ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The Analog-to-Digital (A/D) Converter module has five inputs for the 28-pin devices and eight for the other devices.

The analog input charges a sample and hold capacitor. The output of the sample and hold capacitor is the input into the converter. The converter then generates a digital result of this analog level via successive approximation. The A/D conversion of the analog input signal results in a corresponding 10-bit digital number. The A/D module has high and low voltage reference input that is software selectable to some combination of VDD, Vss, RA2, or RA3.

The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode. To operate in SLEEP, the A/D clock must be derived from the A/D's internal RC oscillator.

The A/D module has four registers. These registers are:

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register0 (ADCON0)
- A/D Control Register1 (ADCON1)

The ADCON0 register, shown in Register 11-1, controls the operation of the A/D module. The ADCON1 register, shown in Register 11-2, configures the functions of the port pins. The port pins can be configured as analog inputs (RA3 can also be the voltage reference), or as digital I/O.

Additional information on using the A/D module can be found in the PICmicro™ Mid-Range MCU Family Reference Manual (DS33023).

REGISTER 11-1: ADCON0 REGISTER (ADDRESS: 1Fh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{\text{DONE}}$	—	ADON
bit 7							bit 0

bit 7-6 **ADCS1:ADCS0:** A/D Conversion Clock Select bits
00 = Fosc/2
01 = Fosc/8
10 = Fosc/32
11 = FRC (clock derived from the internal A/D module RC oscillator)

bit 5-3 **CHS2:CHS0**: Analog Channel Select bits
000 = channel 0, (RA0/AN0)
001 = channel 1, (RA1/AN1)
010 = channel 2, (RA2/AN2)
011 = channel 3, (RA3/AN3)
100 = channel 4, (RA5/AN4)
101 = channel 5, (RE0/AN5)(1)
110 = channel 6, (RE1/AN6)(1)
111 = channel 7, (RE2/AN7)(1)

bit 2 **GO/$\overline{\text{DONE}}$:** A/D Conversion Status bit
If ADON = 1:
1 = A/D conversion in progress (setting this bit starts the A/D conversion)
0 = A/D conversion not in progress (this bit is automatically cleared by hardware when the A/D conversion is complete)

bit 1 **Unimplemented**: Read as '0'

bit 0 **ADON**: A/D On bit
1 = A/D converter module is operating
0 = A/D converter module is shut-off and consumes no operating current

Note 1: These channels are not available on PIC16F873/876 devices.

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
- n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

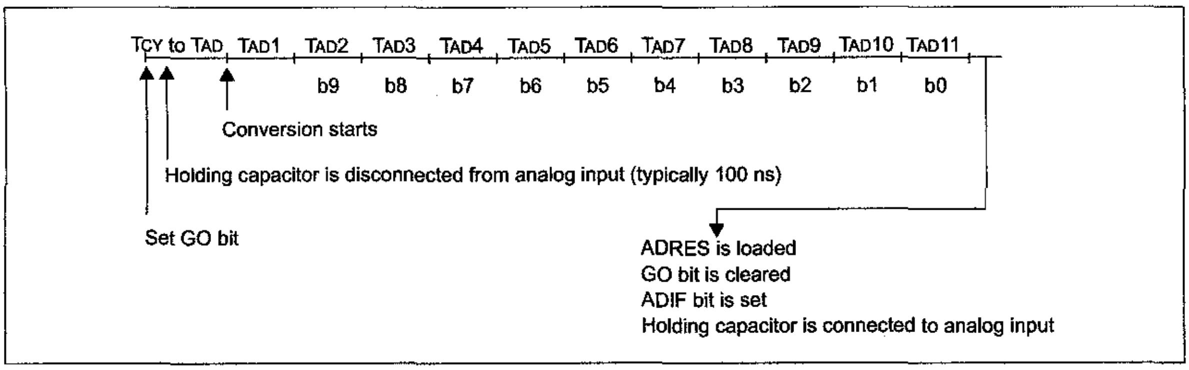
11.4 A/D Conversions

Clearing the GO/$\overline{DONE}$ bit during a conversion will abort the current conversion. The A/D result register pair will NOT be updated with the partially completed A/D conversion sample. That is, the ADRESH:ADRESL registers will continue to contain the value of the last completed conversion (or the last value written to the ADRESH:ADRESL registers). After the A/D conversion is aborted, a 2TAD wait is required before the next acquisition is started. After this 2TAD wait, acquisition on the selected channel is automatically started. The GO/$\overline{DONE}$ bit can then be set to start the conversion.

In Figure 11-3, after the GO bit is set, the first time segment has a minimum of TCY and a maximum of TAD.

> **Note:** The GO/$\overline{DONE}$ bit should **NOT** be set in the same instruction that turns on the A/D.

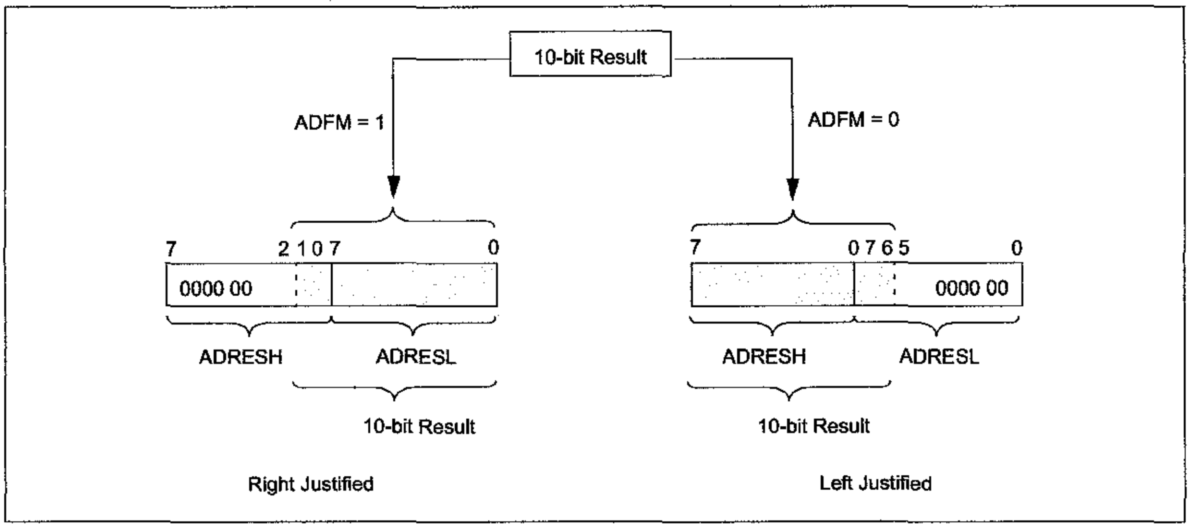
FIGURE 11-3: A/D CONVERSION TAD CYCLES



11.4.1 A/D RESULT REGISTERS

The ADRESH:ADRESL register pair is the location where the 10-bit A/D result is loaded at the completion of the A/D conversion. This register pair is 16-bits wide. The A/D module gives the flexibility to left or right justify the 10-bit result in the 16-bit result register. The A/D Format Select bit (ADFM) controls this justification. Figure 11-4 shows the operation of the A/D result justification. The extra bits are loaded with '0's'. When an A/D result will not overwrite these locations (A/D disable), these registers may be used as two general purpose 8-bit registers.

FIGURE 11-4: A/D RESULT JUSTIFICATION



APPENDIX 8

TECHNICAL DATA MQ-6 GAS SENSOR

FEATURES

* High sensitivity to LPG, iso-butane, propane
* Small sensitivity to alcohol, smoke.
* Fast response . * Stable and long life * Simple drive circuit

APPLICATION

They are used in gas leakage detecting equipments in family and industry, are suitable for detecting of LPG,iso-butane,propane,LNG, avoid the noise of alcohol and cooking fumes and cigarette smoke.

SPECIFICATIONS

A. Standard work condition

Symbol	Parameter name	Technical condition	Remarks
Vc	Circuit voltage	5V±0.1	AC OR DC
V_H	Heating voltage	5V±0.1	AC OR DC
P_L	Load resistance	20KΩ	
R_H	Heater resistance	33Ω±5%	Room Tem
P_H	Heating consumption	less than 750mw	

B. Environment condition

Symbol	Parameter name	Technical condition	Remarks
Tao	Using Tem	-10℃-50℃	
Tas	Storage Tem	-20℃-70℃	
R_H	Related humidity	less than 95%Rh	
O_2	Oxygen concentration	21%(standard condition)Oxygen concentration can affect sensitivity	minimum value is over 2%

C. Sensitivity characteristic

Symbol	Parameter name	Technical parameter	Ramark 2
Rs	Sensing Resistance	10KΩ - 60KΩ (1000ppm LPG)	Detecting concentration scope: 200-10000ppm LPG , iso-butane, propane, LNG
α (1000ppm/ 4000ppm LPG)	Concentration slope rate	≤0.6	
Standard detecting condition	Temp: 20℃±2℃ Vc:5V±0.1 Humidity: 65%±5% Vh: 5V±0.1		
Preheat time	Over 24 hour		

D. Structure and configuration, basic measuring circuit

	Parts	Materials
1	Gas sensing layer	SnO_2
2	Electrode	Au
3	Electrode line	Pt
4	Heater coil	Ni-Cr alloy
5	Tubular ceramic	Al_2O_3
6	Anti-explosion network	Stainless steel gauze (SUS316 100-mesh)
7	Clamp ring	Copper plating Ni
8	Resin base	Bakelite
9	[illegible]	Copper plating Ni

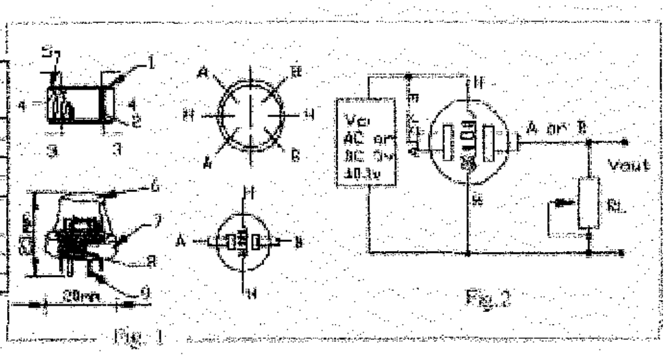
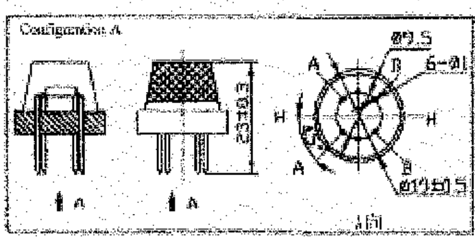
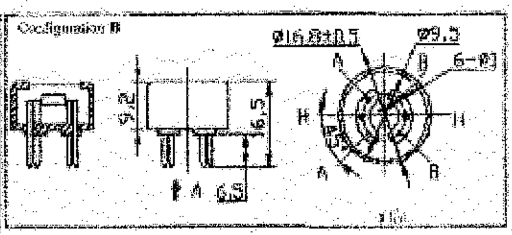


Fig. 1 Fig.2





Structure and configuration of MQ-6 gas sensor is shown as Fig. 1 (Configuration A or B), sensor composed by micro Al_2O_3 ceramic tube, Tin Dioxide (SnO_2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-6 have 6 pin ,4 of them are used to fetch signals, and other 2 are used for providing heating current.

Electric parameter measurement circuit is shown as Fig.2

E. Sensitivity characteristic curve

Fig.2 sensitivity characteristics of the MQ-6

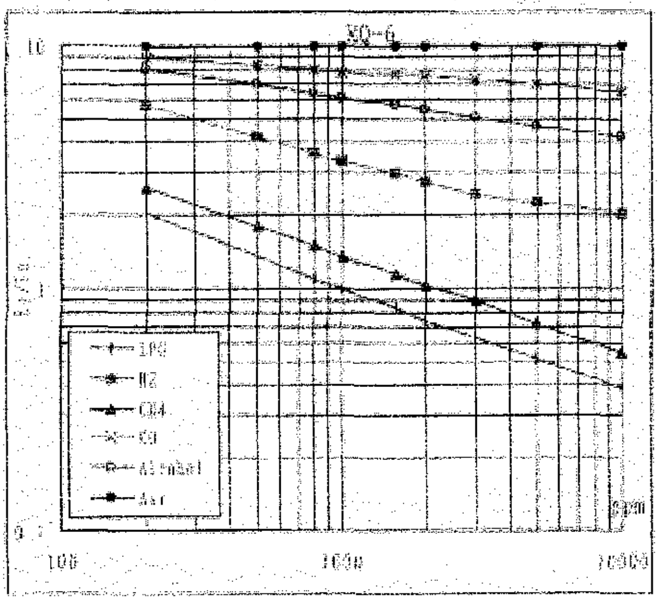


Fig.3 is shows the typical sensitivity characteristics of the MQ-6 for several gases.
in their: Temp: 20℃、
Humidity: 65%、
O_2 concentration 21%
RL=20kΩ
Ro: sensor resistance at 1000ppm of LPG in the clean air.
Rs: sensor resistance at various concentrations of gases.

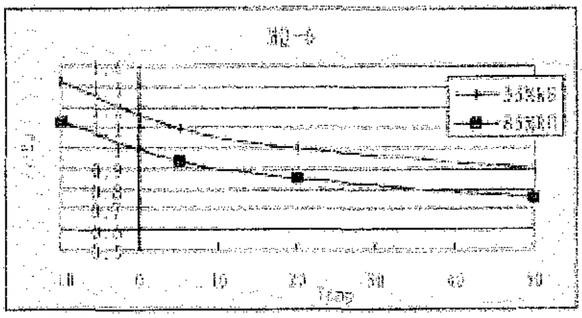


Fig.4 is shows the typical dependence of the MQ-6 on temperature and humidity.
Ro: sensor resistance at 1000ppm of LPG in air at 37%RH and 20 degree.
Rs: sensor resistance at 1000ppm of LPG in air at different temperatures and humidities.

SENSITVITY ADJUSTMENT

Resistance value of MQ-6 is difference to various kinds and various concentration gases. So,When using this components, sensitivity adjustment is very necessary. we recommend that you calibrate the detector for 1000ppm of LPG concentration in air and use value of Load resistance (R_L) about 20KΩ (10KΩ to 47KΩ).

When accurately measuring, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence.

APPENDIX 9

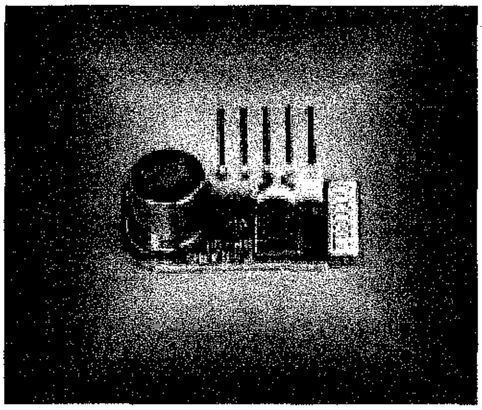
LPM-2610 - pre-calibrated module for LP Gas

Features:

* Factory calibrated
* Temperature compensation circuit
* Low power consumption sensor TGS2610
* Compact size

Applications:

* Residential LP gas alarm



The LPM-2610 is a pre-calibrated module for LP gas alarms which is precisely calibrated in Figaro's humidity and temperature controlled facility.

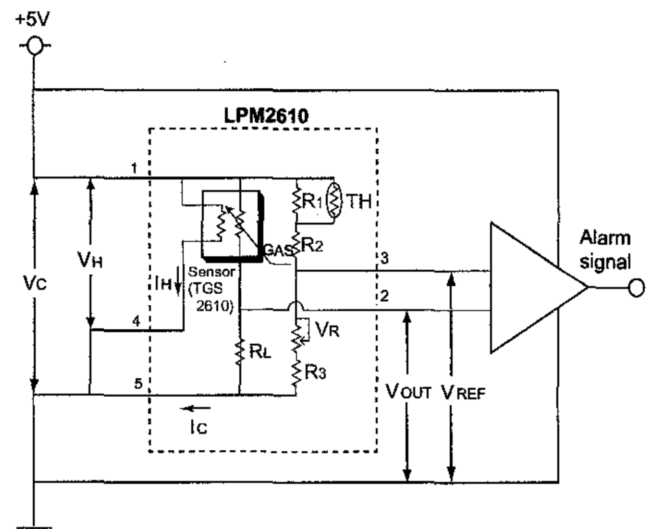
The most important process in manufacturing reliable residential gas alarms is adjusting the alarm point. Calibration is a complicated and time consuming process which also requires a substantial investment in calibration equipment. By eliminating the costly calibration process, this module enables users to easily and simply manufacture residential LP gas alarms. Figaro has taken the complexity out of designing a gas detector circuit by providing users with a temperature compensation circuit which combines a built-in thermistor and individually adjusted load resistor together with Figaro's low power LP gas sensor.

A connector allows easy replacement of the module for the purpose of periodic sensor renewal. This input/output connector enables easy installation of the module into the gas detectors' mother board. This same mother board can be used for both methane and LPG gas detectors by simply changing the module.

This module is designed to meet the performance requirements of BS7348, UNI CEI-70028, EN50194, and UL1484.

Please refer to *"Technical Information for TGS2610"* for sensor sensitivity characteristics. Refer to *"Application Notes for TGS2610"* for further information regarding circuit design.

Circuit Diagram



V_C: Circuit voltage
V_H: Heater voltage
V_{OUT}: Output voltage
V_{REF}: Reference voltage
I_C: Circuit current
I_H: Heater current

Basic Pin Connection

A regulated voltage of 5V DC should be applied to Pin #1. A voltage comparator should be connected to Pins #2 and 3. A circuit for detecting breakage of the heater may be connected to Pin #4 (in which case, Pins #4 and 5 should be connected separately to the GND).

When the gas sensor module is exposed to a concentration of target gas which exceeds the desired alarming point, the value of Vout will reach or exceed the value of V_{REF}, causing the module to reach the alarm condition.

NOTE: As described in Sec. 2-6 of *"Technical Information for TGS2610"*, when energizing the sensor after an unpowered period, the sensor's resistance (Rs) drops sharply for the first few seconds after energizing, regardless of the presence of gases, before recovering to a stable level. This 'initial action' may cause activation of an alarm during the first few moments of energizing since V_{RL} would exceed V_{ref}. To prevent unnecessary alarms during sensor warmup, a circuit modification such as that shown in Sec. 1-7 of *"Application Notes for TGS2610"* should be used.

Parts List:

Symbol	Part	Spec.	Maker	Model #	Qty
R_1	Carbon resistor	12kΩ 1/8W	Panasonic	ERJ8GEYJ123A	1
R_2	Carbon resistor	430Ω 1/8W	Panasonic	ERJ8GEYJ431A	1
R_3	Carbon resistor	4.3kΩ 1/8W	Panasonic	ERJ8GEYJ432A	1
R_L	Carbon resistor	Var. 1/8W	Panasonic	ERJ8GEYJxxxA	1
V	Potentiometer	10kΩ 1/5W	Panasonic	EVML1GA00B14	1
TH	Thermistor	10kΩ at 25°C B const.=3400	Mitsubishi Materials	SC20-3I103KT	1
Sensor	Gas Sensor	-	Figaro	TGS2610	1
CN	Connector	-	Nichiatsu	MB5P-90S	1

Specifications:

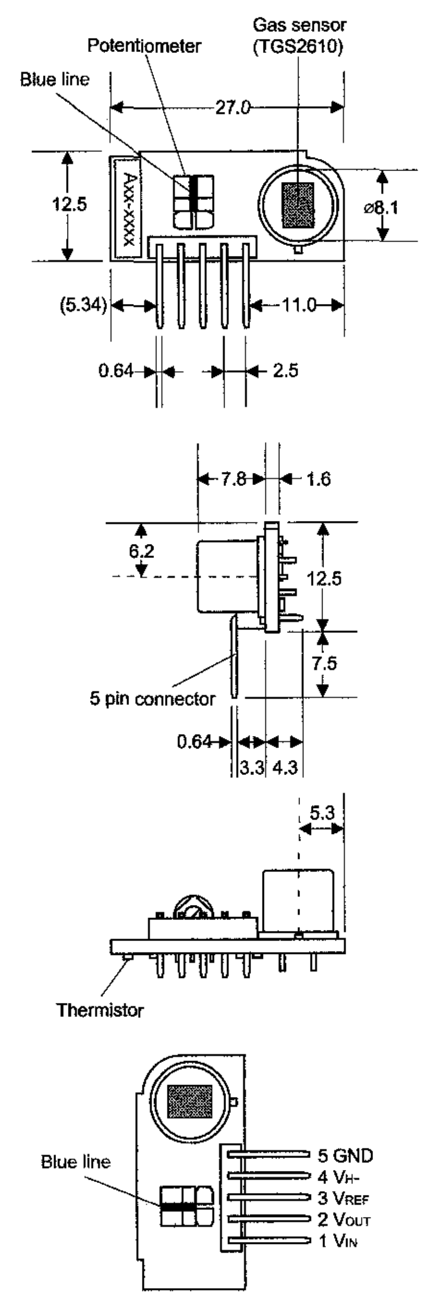
Module number			LPM 2610
Standard test conditions	Test gas conditions		1800±50ppm isobutane in air at 20±2°C, 65±5%RH
	Circuit conditions		V_H = 5.0±0.05V DC V_C = 5.0±0.05V DC
	Preheating period prior to test		2 days
Electrical characteristics under standard test conditions	Reference voltage	$V_{REF(STD)}$	$V_{out(STD)}$ ±0.5V DC
	Output voltage	$V_{out(STD)}$	2.5±0.5V DC

Electrical Characteristics:

Recommended operating conditions	Heater voltage	V_H	5.0±0.2V DC
	Circuit voltage	V_C	5.0±0.2V DC
	Minimum impedance between Pin#2 and GND		2.5MΩ
	Minimum impedance between Pin#3 and GND		
	Operating conditions		0~40°C, 30~95%RH
	Temperature differential between inside and outside detector casing		≤10°C max. (see NOTE)
Electrical characteristics under operating conditions	Heater current *(current between Pins #1 and 4)*	I_H	56±5mA
	Circuit current *(current between Pins #1 and 5)*	I_C	10mA (max.)
	Reference voltage	V_{REF}	1.0~4.0V DC
	Output voltage	V_{out}	0.05~(Vc-0.05)V DC

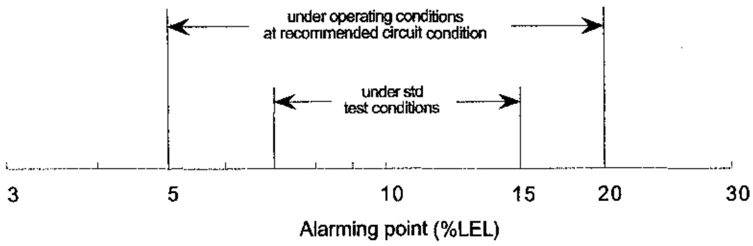
NOTE: Due to heat generated by circuit components, if the internal temperature of the detector exceeds the environmental temperture outside the detector casing by 10°C or more, the calibrated alarm concentration would drift due to drifting of Vref. If users are unable to design detectors so as to keep this temperature differential below 10°C, please consult with Figaro.

Structure and Dimensions:



IMPORTANT NOTE: *The original setting of the potentiometer should be checked prior to usage of the module to verify that it is in the calibrated position. LPM2610 has a blue line on the potentiometer which should be in alignment.*

Expected performance:



Expected performance of LP gas detectors
using LPM-2610 and 10% LEL alarming point

NOTE: When using LPM2610, typical alarm tolerances for 10%LEL of LP gas such as those shown in the figure above can be expected. However, in actual usage, alarm thresholds may vary since the threshold is also affected by such factors as the tolerances of test conditions and heat generation inside the gas detection enclosure. As a result, Figaro neither expressly nor impliedly warrants the performance shown in this figure. If a large difference between the expected and actual performance of detectors is noticed, please consult with Figaro.

Absolute Maximum Ratings:

Absolute maximum ratings (see NOTE)	Circuit voltage	Vc	-0.3~+5.5V DC
	Heater voltage	V_H	-0.3~+5.5V DC *(max. of 2 minutes at 5.5V)*
	Operating temperature		-15~+55°C *(max. 95%RH)*
	Storage temperature		-20~+60°C *(avoid condensation)*
	Soldering temperature		260°C *(max. in 10 sec.)*

NOTE: Detectors should be designed according to "Recommended Operating Conditions" as shown above. However, detector circuits should also be designed not to exceed "Absolute Maximum Ratings" under any circumstances. To exceed these ratings may cause damage or deterioration of the sensor.

For applications involving usage of LPM2610 for applications other than residential LP gas alarms, please consult with Figaro.

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REV: 03/02