TARGET TRACKING SYSTEM USING ULTRASONIC SENSORS

By

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CERTIFICATION OF APPROVAL

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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.

Mohamad Ridzuan Bin Sani

ABSTRACT

The project titled 'Target Tracking System using Ultrasonic Sensors' is based on improving the security system in Malaysia. Statistic by Polis Diraja Malaysia (Royal Malaysian Police) shown that compared to the year 2006, the crime is increases by 13.4 percent in 2007. Thus, this project focuses on expanding the application of ultrasonic technology into closed circuit televisions (CCTV) which has been widely use in many other sectors but never been applied in security system in Malaysia. The outcome of this project is a working prototype of a target tracking system using ultrasonic sensor which can detect and track a moving object within the radius of 3 meters. This project uses one transmitter and two receivers bound on both side of the transmitter. On top of the transmitter and receivers is the camera to capture image of the moving object. The method used in tracking the moving object is by comparing the voltage of both receivers and controlled by the PIC used in this project which is the PIC16F877. The working prototype has been successfully completed and it is very important in fighting crime if it is installed accordingly.

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LIST OF ABBREVIATIONS

RISC	REDUCE INSTRUCTION SET
CMOS	COMPLEMENTARY METAL OXIDE SEMICONDUCTOR
EEPROM	ELECTRICALLY ERASABLE, PROGRAMMABLE, READ-ONLY MEMORY
PIC	PROGRAMMABLE INTEGRATED CIRCUIT
CCTV	CLOSED CIRCUIT TELEVISION

CHAPTER 1
INTRODUCTION

1.1 Background of Study

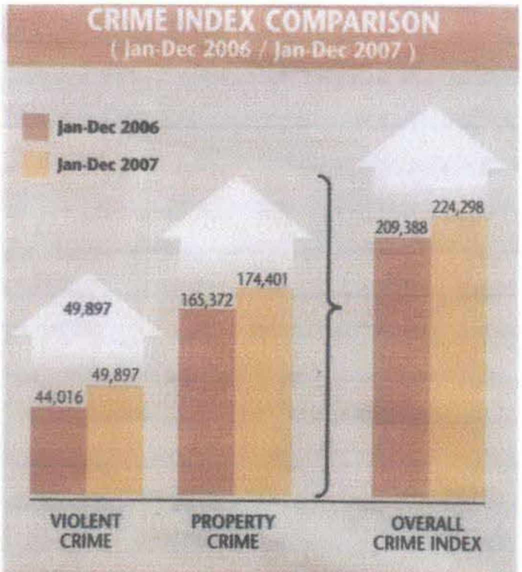
In security risk areas, people often install alarms which are triggered by sensors. There are many types of sensors being used is the security systems. As the technologies expand rapidly through the time, security systems have forward from alarms to cameras and even computers. There are many kinds of sensors such as infrared sensor, microwave sensor, radio frequency and ultrasonic sensor. However, for ultrasonic sensor, it is only used to trigger alarm. Because of the uniqueness of ultrasonic sensor which is very sensitive to movement, it has become the disadvantage when applied to alarm because it triggers false alarm even when it detects insects or changes in air flow. Because of the high sensitivity of ultrasonic sensor, people have stop expanding the technology of ultrasonic into security system.

This project uses ultrasonic sound to detect moving objects and track them. Ultrasonic burst of appropriate energy is produce by a transmitter. The reflected sound wave is detected using ultrasonic receivers mount beside transmitter on either side. If there is a reflected sound, the receivers will sense it. The time difference between the left and the right receivers is calculated by a microcontroller and instruct the sound pointer base to rotate towards the object.

1.2 Problem Statements

1.2.1 Problem Identification

In Malaysia, news of crime popped out everyday and very frequently. According to statistics in figure 1.1, the crime statistics increases by 13.4 percent in year 2007 compared to year 2007. This worries the Prime Minister, Datuk Seri Abdullah Ahmad Badawi as well as the Malaysian citizens.



IN THE STATES

		Jan-Dec 06	Jan-Dec 07	+/-	%
1	KEDAH	1,682	2,439	757	45.01
2	SARAWAK	2,167	2,922	755	34.84
3	KELANTAN	961	1,198	237	24.66
4	SELANGOR	12,395	15,104	2,709	21.86
5	PAHANG	1,077	1,263	186	17.27
6	SABAH	1,702	1,919	217	12.75
7	PENANG	2,951	3,280	329	11.15
8	MALACCA	1,167	1,265	98	8.40
9	TERENGGANU	709	751	42	5.92
10	PERAK	3,039	3,211	172	5.66
11	JOHOR	6,611	6,900	289	4.37
12	KUALA LUMPUR	7,539	7,639	100	1.33
13	N. SEMBILAN	1,843	1,857	14	0.76
14	PERLIS	173	149	-24	-13.87
	MALAYSIA	**44,016**	**49,897**	**5,881**	**13.36**

PROPERTY CRIME

Offences	Jan-Dec 06	Jan-Dec 07	+/-	%
Burglary (night)	20,080	24,440	4,360	21.71
Car thefts	11,154	12,427	1,273	11.41
Thefts	42,472	44,617	2,145	5.05
Burglary (day)	8,792	9,159	367	4.17
Motorcycle thefts	65,462	67,584	2,122	3.24
Snatch thefts	11,074	11,127	53	0.48
Van, lorry and heavy machinery thefts	6,338	5,047	-1,291	-20.37
TOTAL	**165,372**	**174,401**	**9,029**	**5.46**

VIOLENT CRIME

Offences	Jan-Dec 06	Jan-Dec 07	+/-	%
Gang robbery without firearms	2,723	7,067	4,344	159.53
Rape	2,454	3,177	723	29.46
Criminal intimidation	6,699	8,119	1,420	21.20
Assaults	5,843	6,806	963	16.48
Gang robbery with firearms	67	77	10	14.93
Rioting	2,291	2,608	317	13.84
Molest	2,064	2,320	256	12.40
Extortion	1,554	1,692	138	8.88
Murder	606	588	-18	-2.97
Robbery without firearms	19,467	17,241	-2,226	-11.43
Robbery with firearms	248	202	-46	-18.55
TOTAL	**44,016**	**49,897**	**5,881**	**13.36**

Figure 1.1: Crime index comparison between the year 2006 and year 2007 [1]

The crime index specifies on the violent crime and property crime whereby both showing increment. Thereby, the overall crime index increases to total 224 298 cases in year 2007. One of the ways taken by the authorities in fighting crime is by installing more closed-circuit televisions (CCTV) as urged by Inspector-General of Police Tan Sri Musa Hassan urged private and public sector to spend a bit more when it came by to buying CCTVs. However, the normal CCTV does not perform the job well due to some limitations of recent technology which do not provide clear image which has been captured. A CCTV can help to retrieve the image of wrong doers if only the image is clear. There is an unsolved murder case of Nurin Jazlin where the building where Nurin Jazlin was found in a bag is equipped with a CCTV but the image captured is very blur and the Malaysian Police did not able to retrieve the image. The picture is sent to the Federal Bureau of Investigation (FBI) of the United States of America but they also did not manage to get the clear image of the person of even the motorcycle registration number as shown in figure 1.2.

Figure 1.2: One of the poor quality image captured on CCTV near the area Nurin Jazlin's body was found [1]

1.2.2 Project Significance

By having this project, it can be used in high security risk areas for monitoring human presence to reduce the number of crimes as advised by the Prime Minister Datuk Seri Abdullah Ahmad Badawi. It is proven from the increasing cases of reported crime in 2007 that police officers, guards and citizens are not enough to monitor these high security risk areas especially for long period of continuous time and to reduce crime. As the prime minister and the general of police urged to install more CCTVs and to put in more money to have a high quality CCTV, this is where the target tracking system using ultrasonic sensors comes in. It gives 24 hours, 7days a week monitoring and tracking system whereby trespassers can be detected before they commit any crimes. With innovative technology been put in the CCTVs, the CCTV can be equipped with ultrasonic sensors which can detect and track moving object for better image caption.

1.3 Project Objectives

The objectives of this project is to design and construct a prototype of a target tracking system using ultrasonic sensor which would be able to help the security officers to fight crimes. The target tracking system will burst ultrasonic sound wave t the surroundings and the reflected wave is evaluated to identify whether there moving objects within the area. Then, the target tracking system will follow the movement of the object throughout the respective area. The cost is to be minimized to achieve minimal expenses by the implementation using the PIC microcontroller.

There are a few objectives need to be achieved by the end of project completion. The objectives will be stated clearly to make sure the success of the project implemented. The objectives of this project are as the following section:

1.3.1 To come out with a working prototype of a target tracking system using ultrasonic sensors

The prototype of the target tracking system using ultrasonic sensor must be working according to the specification. The design of circuits and structure of hardware must be reliable and maintainable.

1.3.2 To detect and track at least one moving object using ultrasonic sensors

The system of target tracking system must at least able to detect and track at least one moving object within the area. If the system can target and track one moving object, it can be improvised in the future.

1.3.3 To detect and track moving object(s) in the range of 3 meters in radius

The area which has been specified as the coverage for the target tracking system is within the range of 3 meters. This is the maximum range that that target tracking system can work efficiently. For more than 3 meters, the efficiency will reduce gradually. However, the range can always be expanded up to 10 meters with some modification to the transmitter and receiver circuits.

1.3.4 To expand the ultrasonic technology in security system

With the completion of this project, the technology in security system is expanding with the target tracking system using ultrasonic sensor. With this technology, it can help to fight crime and reduce the number of crimes in Malaysia.

1.4 Scope of Study

Based on the literature and earlier research, there are many security systems with different types of technology based systems. However, in Malaysia, recently none of them uses ultrasonic sensors in their system to track moving objects. Previously, ultrasonic sensors have been used in industry for non-destructive testing, in medical ultrasonography, in agriculture and in weather forecast. In this project, ultrasonic technology is being extended for security system.

This project is designed to be completed successfully within a year which is in the time frame of 2 semesters. With essential time allocated for this project, the outcome of this project will be a working prototype which can detect, target and track any moving objects as stated in the objectives.

The scope of study can be divided into three main parts in which interdependency and coordination between all three parts must be developed to produce a functional prototype of target tracking system using ultrasonic sensor.

1.4.1 Controllers and Programming

Controllers are the brain of the system. There are various choices of controllers to choose from. However, the cost is the main constraint for this project. Therefore, PIC microcontroller has to be chosen carefully so that the system will be cost effective. The programming language required for this controller is C programming

1.4.2 Electrical Circuits

The ultrasonic sensor is the main system. However, there are other electrical circuitry is required for proper function of mechanical devices.

1.4.3 Hardware Mechanism

Motor is the mechanism which will be used to rotate the tracking system. Proper motor needs to be selected for desired output. Three types of motors have been identified for the system; Continuous Motor, Stepper Motor and Servo Motor.

CHAPTER 2
LITERATURE REVIEW

2.1 Ultrasonic sensors

Ultrasonic sensors work on a principle which evaluates attributes of a target by interpreting the echoes from radio or sound waves respectively. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object.

Systems typically use a transducer which generates sound waves in the ultrasonic range, above 20,000 hertz, by converting electrical energy into sound, then upon receiving the echo convert the sound waves into electrical energy which can be measured and displayed [2].

2.2 Transducers

An ultrasonic transducer is a device that converts energy into ultrasound, or sound waves above the normal range of human hearing. Piezoelectric transducer is the term used for transducers which convert electrical energy into sound. Piezoelectric crystals have the property of changing size when a voltage is applied, thus applying an alternating voltage (AC) across them causes them to oscillate at very high frequencies, thus producing very high frequency sound waves [2].

2.3 Detectors

Since piezoelectric crystals generate a voltage when force is applied to them, the same crystal can be used as an ultrasonic detector. Some systems use separate transmitter and receiver components while others combine both in a single piezoelectric transceiver [2].

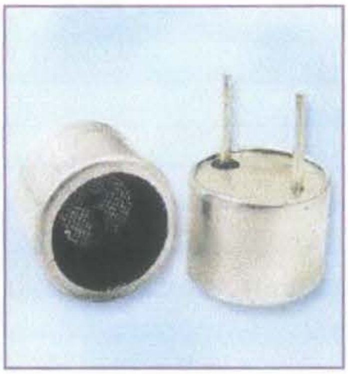


Figure 2.1: Low Noise Ultrasonic Transducers and Detectors [3]

The specifications for the low-noise ultrasonic transducers are as below:

- Nominal frequency (KHz): 40 +/- 1
- Sensitivity (dB/V/ubar): > / = 67
- Sound pressure level (dB): > / = 112
- Impedance (ohm): < / = 1500
- Capacitance (pF): 2000 +/- 20%
- Diameter (mm): 16.1
- Pin diameter (mm): 1.0
- Pin distance (mm): 10.0
- Case height (mm): 12.0
- Total height (mm): 22.5
- Applications:
    - Pest repellers, animal repellers, remote controllers, intruder alarm system, flow meters, level controllers,
    - powder sensors and object detectors
- Remarks
    - Sound pressure level: 0dB vs 0.0002 ubar, measured at 10V rms, 30cm distance
    - Sensitivity: 0dB vs 1V/ubar

2.4 Ultrasonic Application

Ultrasonic has been widely used in many applications because of the benefits and advantages compared to other sensors. Unlike other waves, ultrasonic wave behaves differently where it uses high frequency sound wave in its propagation. Listed below are some established applications of ultrasonic technology in real life:

SONAR stands for Sound Navigation and Ranging. It is a technique that uses sound propagation under water to navigate, communicate or to detect other vessels. There are two kinds of SONAR which are active and passive. Sonar may be used as a means of acoustic location. The frequencies used in sonar systems vary from infrasonic to ultrasonic [4].

SONAR has been used in many civil applications like fisheries, to measure the sea level, to find missing vehicle in the sea such as crashed air planes or boats, to find net location and also as underwater security. It is also widely used in the submarine technology acts as radar to look for other objects in the surrounding as well as to move under the sea without hitting the seabed or any obstacles. SONAR technology is also installed onto the head of torpedo to find its target to be used in anti-submarine application.

In **medical**, ultrasonography is used as a diagnostic imaging technique to visualize muscles and internal organs, their size, structures and possible pathologies or lesions. Obstetric sonography is commonly used during pregnancy and is widely recognized by the public. There are a plethora of diagnostic and therapeutic applications practiced in medicine. Typical diagnostic sonography scanners operate in the frequency range of 2 to 15 megahertz, hundreds of times greater than this limit. The choice of frequency is a trade-off between spatial resolution of the image and imaging depth: lower frequencies produce less resolution but image deeper into the body [5].

A group of researcher tries to create a smart environment where it is defined as monitoring activities of people using ultrasonic sensors. They developed several scenarios in which ultrasonic sensors are used for monitoring of patients and the elderly. In each scenario, different algorithms approaches are used for data fusion and sensor selection using quality-based or time division approaches. The trajectory-matching algorithms are devised to classify trajectories of movement of people in indoor environments. The trajectories are divided into several routine classes and the current trajectory is compared against the known routine trajectories. The initial results are quite promising and there is a potential usability of ultrasonic sensors in monitoring indoor movements of people in capturing and classifying trajectories.

Ultrasonic is also applied in the industry especially for Migatron Corporation where the company developed a wide variety of high-quality standard ultrasonic sensors and controllers, as well as design assistance for semi-custom units. Ultrasonic sensors provide cost effective sensing method with unique properties not possessed by other sensing technologies. By using a wide variety of ultrasonic transducers and several different frequency ranges, an ultrasonic sensor can be designed to solve many application problems that are cost prohibitive or simply cannot be solved by other sensors.

- **Long range detection:** In industrial sensing, more and more applications require detection over distance. Ultrasonic sensors detect over long ranges up to forty feet, while limit switches and inductive sensors do not.
- **Broad area detection:** While some photo electric sensors can detect over long distances they lack the ability to detect over a wide area without using a large number of sensors. The advantage of ultrasonic sensors is that both wide and narrow areas can be covered. All it takes is the proper ultrasonic transducer selection.
- **Widest range of target materials:** Only ultrasonic sensors are impervious to target material composition. The target material can be clear, solid, liquid, porous, soft, and wood and any color because all can be detected.
- **Non contact distance measuring:** Because sound can be timed from when it leaves the transducer to when it returns, distance measuring is easy and

accurate to .05% of range which equates to +or- .002 of an inch at a distance of 4 inches [6].

When used for sensing functions, the ultrasonic method has unique advantages over conventional sensors...

- Measures and detects distances to moving objects.
- Impervious to target materials, surface and color.
- Solid-state units have virtually unlimited, maintenance-free lifespan.
- Detects small objects over long operating distances.
- Resistant to external disturbances such as vibration, infrared radiation, ambient noise and EMI radiation.
- Ultrasonic sensors are not affected by dust, dirt or high-moisture environments [6].

2.5 Application in Robotic System

The RoBat project is a target tracking system using ultrasonic sensors using one transmitter and two receivers mounted on both sides of the transmitter which are independently orientable that can rotates 360 degrees to receive the echo thus detect and track moving objects. The RoBat is invented to copy the movement of Rhinolophid and Hipposiderid bats in evaluating the surrounding to avoid hitting obstacles during flight. It is implemented in the RoBat as a target tracking system for collision avoidance.

The Autonomous Target Tracking System Based on Fuzzy Logic Algorithm also uses ultrasonic technology but the controller used is the fuzzy logic. The basic ultrasonic circuit is implemented with a great brain of fuzzy logic which can target and track moving objects using the echo received thus calculating them. Real time mobile robot sonar with interference rejection is a new technology which can detect and track up to 8 moving objects at a time within a confined space of 3 sq. meters, by using 8 sets of ultrasonic transmitter and receiver.

To help the security guards on the gate, a technology called gate barriers is used to detect appearance of cars as well as to avoid the gate hitting cars or human being passing through the gates. It uses ultrasonic sensors to detect any presence of objects near the gate.

2.6 Passive Ultrasonic in Security System

The passive Ultrasonic sensor is a motion detection device that "listens" for ultrasonic sound energy in a protected area, and reacts to high frequencies associated with intrusion attempts.

The passive ultrasonic sensor detects the frequencies that have a range between 20 - 30 KHz. Frequencies in this range are associated with metal striking metal, hissing of an acetylene torch, and shattering of concrete or brick. The sound generated is transmitted through the surrounding air and travels in a wave type motion. When the sound wave reaches the detection sensor it determines if the frequency is characteristic of an intrusion. If the criteria are met, an alarm signal is generated [7].

2.7 Active Ultrasonic in Security System

The Active Ultrasonic sensor is a motion detecting device that emits ultrasonic sound energy into a monitored area and reacts to a change in the reflected energy pattern.

Ultrasonic sensors use a technique based on a frequency shift in reflected energy to detect intruders. Ultrasonic sound is transmitted from the device in the form of energy. The sound uses air as its medium and travels in a wave type motion. The wave is reflected back from the surroundings in the room/hallway and the device "hears" a pitch characteristic of the protected environment. When an intruder enters the room, the wave pattern is disturbed and reflected back more quickly, thus increasing the pitch and signaling an alarm [7]

Applications: Typically, ultrasonic sensors are mounted on the wall or ceiling. Ultrasonic sensors can be used in conjunction with a passive device (e.g., PIR) to provide a greater probability of detection (P_D). However, this may also increase the false alarm rate (FAR), depending on environmental characteristics of the monitored area. Ultrasonic sensors are not affected by heat, thus changes in the thermal environment do not hinder its detection ability. Ultrasonic energy is easily contained within a selected area avoiding the problem of the energy passing through walls and detecting activity outside the protected zone.

Conditions for Unreliable Detection: Ultrasonic energy will not pass through most substantive objects and material, (e.g. storage, shelving), thus creating dead zones within the coverage area where the sensor is ineffective. The sensor must be positioned so that the dead zones are minimal. Also, extreme changes in temperature or humidity from the initial calibration may cause a hindrance in detection reliability.

Causes for Nuisance Alarms: Some of the most common stimuli that cause ultrasonic sensors to false alarm are air movement from heating, air conditioning systems, drafts from doors and windows, hissing from pipes, and telephone rings. All of these stimuli can create noise near or in the ultrasonic range, thus triggering an alarm. Also anything that causes movement, such as animals, has the potential to cause an alarm.

Typical Defeat Measures: Slow horizontal movement by an intruder across the area of coverage is often difficult for ultrasonic sensors to detect. Proper calibration is needed to ensure that slow moving intruders will be detected. In addition, a knowledgeable and properly equipped intruder can use special "test lights" to detect coverage patterns and circumvent these areas.

ACTIVE ULTRASONIC MOTION SENSOR

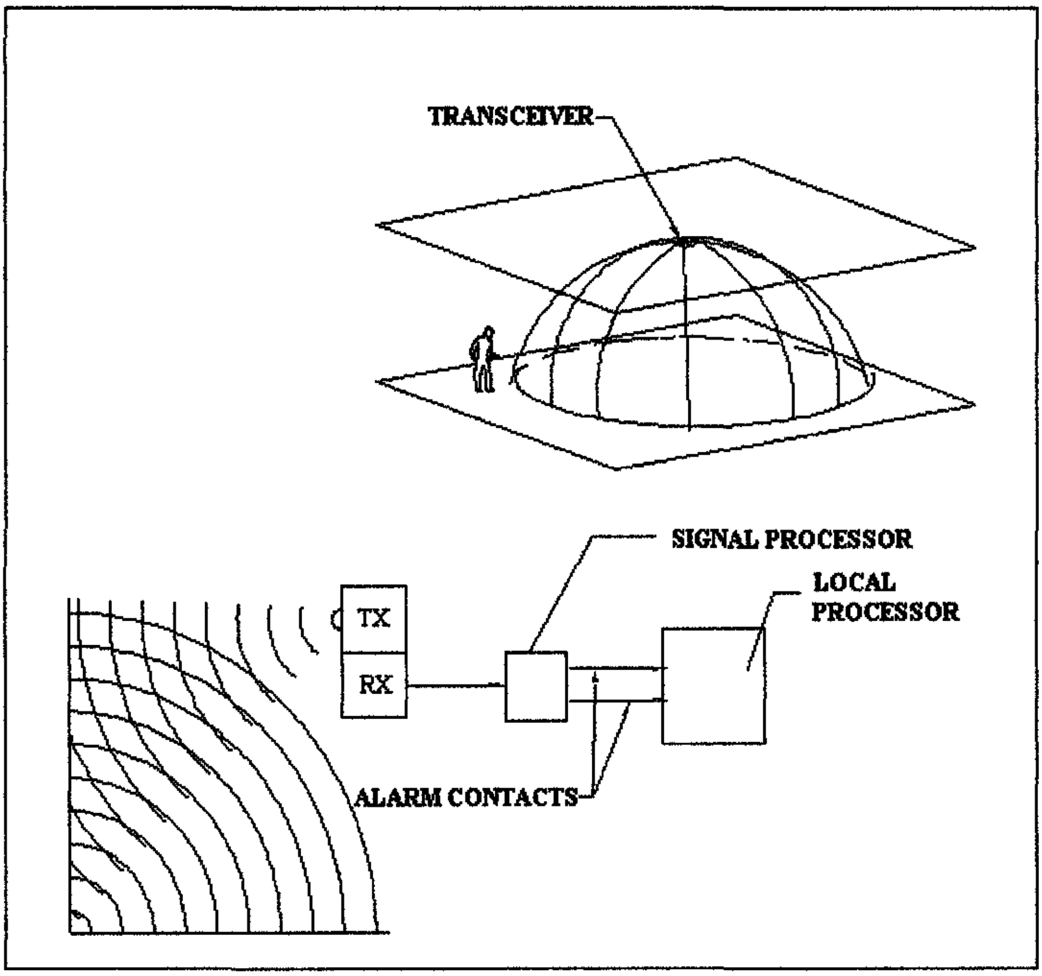


Figure 2.2: Application of active ultrasonic motion sensor in security system [7]

Figure 2.2 illustrates the application of ultrasonic motion sensor in security system where it triggers alarm when a motion is detected.

2.8 Target Tracking System Using Ultrasonic Sensor in Security Application

At present, ultrasonic sensor has been widely used in various applications while target tracking system using ultrasonic sensor also been implemented in robotic system mainly for collision avoidance and for monitoring movement of robots in a specific place.

The application of target tracking system using ultrasonic sensor has never been implemented in security system in Malaysia yet. The usage of ultrasonic sensor in security system is restricted to the alarm system as discussed in earlier chapter.

2.9 Hardware Mechanism

Motor is most probably the hardware which rotates the target tracking system. For this project, several motors were analyzed and the motors are:

DC motor: the common motor normally used to drive continuously in one direction. It only stops when the power supply is removed.

Stepper motor: application of power causes the shaft to rotate a few degrees and then stop. Continuous rotation of the shaft requires the power to be pulsed to the motor.

Servo motor: strong motor which can only move in 180 degrees in direction.

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 Procedure Identification

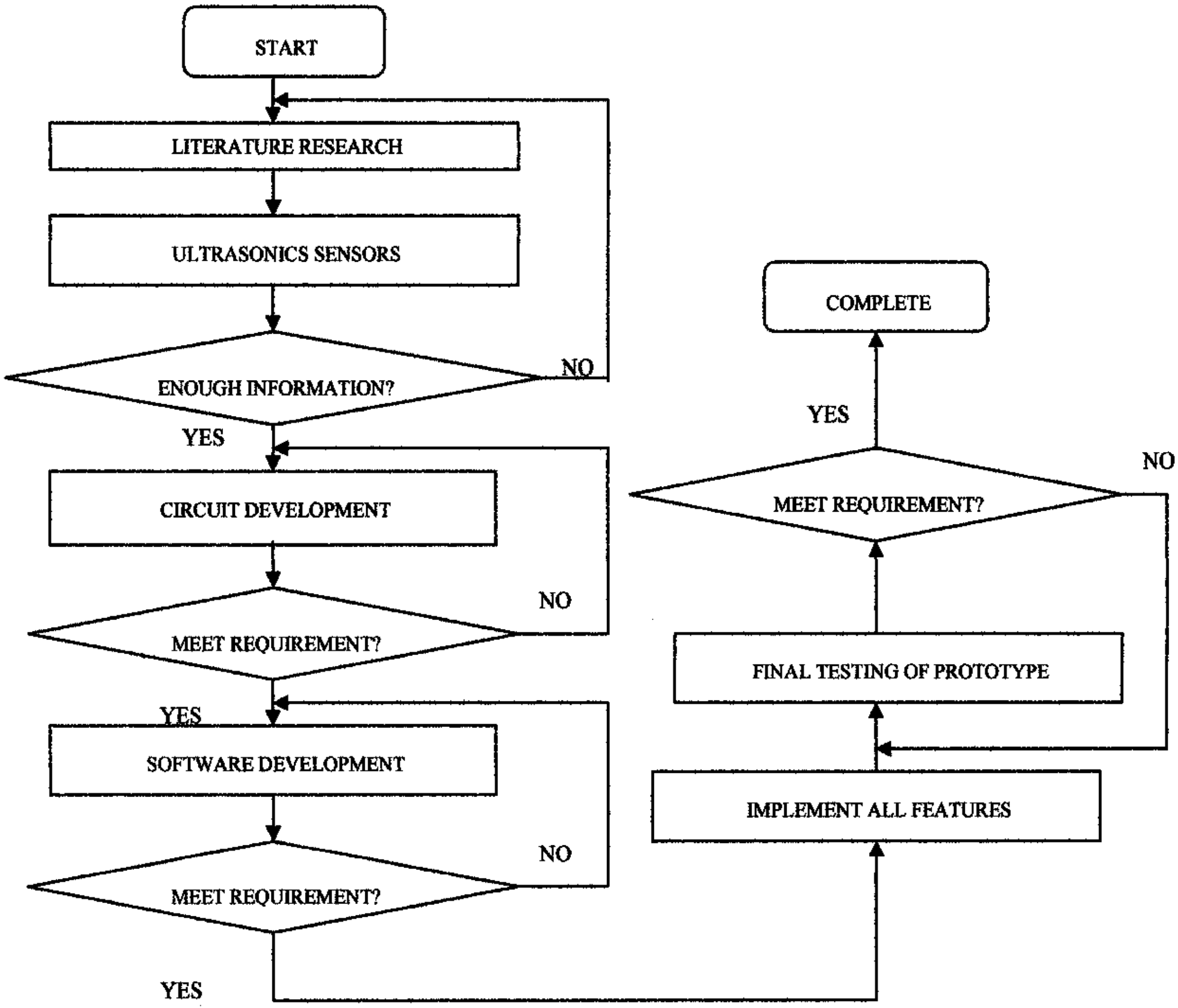


Figure 3.1 Methodology Chart for the project

Figure 3.1 shows the methodology chart for the project beginning with the start of the project until the project finally completed.

3.2 Stages Achievements

3.2.1 Literature Research

The project is done with researching the material to be used during the next stages which is followed by the circuit development stage. Research is done in several ways which are:

- by searching through the internet for relevant journals and technical papers of people's work regarding target tracking system using ultrasonic sensors
- researching the previous projects from the information resource centre(IRC) done by seniors in ultrasonic sensors scope of study
- consultation with lecturers who are experts in sensor and microcontroller

The literature review section is completed where sufficient information of tracking system using ultrasonic sensors development being investigated and the outcomes are as follows:

- The definition of ultrasonic, ultrasonic sensors, transducers, receivers and applications of ultrasonic recently.
- Ultrasonic technology has been used for quite sometime and still developing but it can be expanded to security system since the recent technology uses ultrasonic sensors in security alarm, to monitor patient and elderly in hospital, to detect object at gate and etc. but in target tracking system for security, it is still under research.
- In target tracking system using ultrasonic sensors, the technology is widely used in robotic system for example for obstacle avoidance, path tracker and many more.

The research is carried farther into more specific area of having the rough design of the ultrasonic sensors with a single transducers and two receivers at both side which can rotate 360 degree to receive the echo, the time difference between the echo receive by both receivers been calculated by a microcontroller thus targeting the moving object. Figure below shows a target tracking system robot using ultrasonic sensors called RoBat which has been taken as a reference for design of the platform of this project as discussed in literature review session.

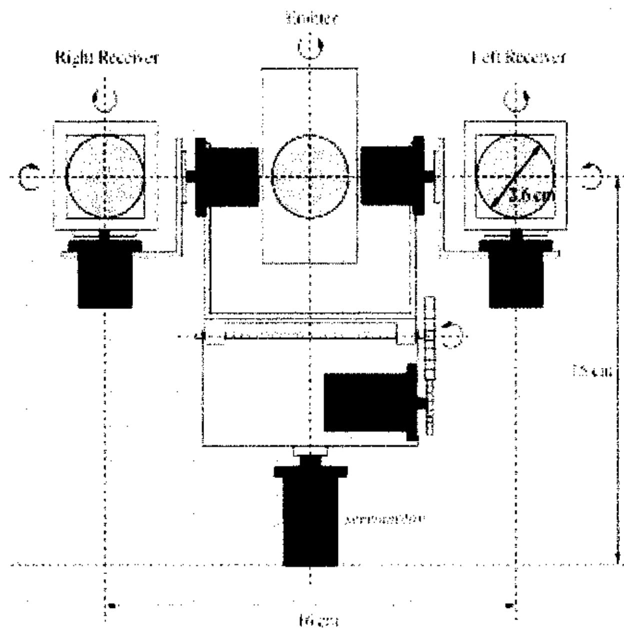


Figure 3.2: The platform of RoBat project [8]

The basic idea of the platform will be quite same with the RoBat project as shown in figure 3.2. The platform consists of a transmitter in the middle with two receivers at both sides which are independently rotatable. However, some modifications were made to reduce cost and for the simplicity of the project.

3.2.2 Project Flow Diagram

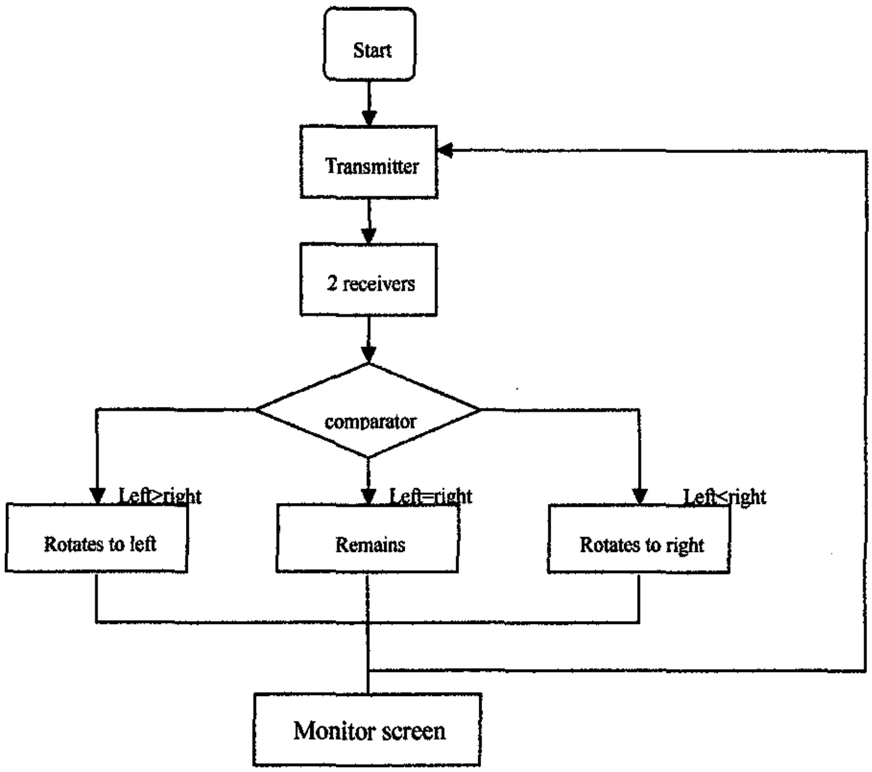


Figure 3.3: Project Flow Diagram

The flow diagram in figure 3.3 shows the project flow from the beginning where the transmitter will transmit ultrasonic signal and will be received by 2 receivers on the both side of the transmitter. The output of both receivers are compared via a comparator which will give instructions to the microcontroller whether to instruct the stepper motor to turn left, right or remain idle. The process is then repeated infinitely.

3.2.3 Circuit Development

The project is then continued with circuit development where the circuitry of the ultrasonic transmitter, receivers, and stepper motor are used. The next stage of the circuit development is where the circuits of transmitter, receivers and stepper motor are connected to the PIC according to the I/O ports. The circuit diagram and the results of transmitter and receiver circuit will be discussed in Chapter 4.

3.2.4 Software Development

The software which can be used in this project is mainly to program the PIC by using Warp 13 software which is connected to the Warp 13 programmer board to program the PIC. The C language code has to be completed first before burning it onto the PIC. Thereby the circuit will only complete once the PIC being properly programmed.

To start of with microcontroller part, there are two programmable integrated circuits (PIC) which are the PIC16F84 and the 89c8252 which can work together or separately as the brain of the target tracking system. Both microcontrollers have their advantages and disadvantages which are:

> **PIC16F84** is small with 18 pins is simple and easier to program and manage but the disadvantages is it has limited ports thus need more than one microcontroller to manage the requirements for a larger usage.
>
> **89c8252** is bigger than PIC16F84 with 40 pins. Has more features and more memories compared to the 16F84 but the draw back is that it is more complicated and hard to program.

There is another microcontroller which can be used which is the PIC16F877 where it has its own analogue to digital converters to receive the sound wave and convert them into readable digital wave for the microprocessor. The main advantages of using this model of microcontroller is that saves money to buy the microcontroller as it can stand alone, saves space compared to using two or more controllers, saves time because it is easier to program and most important it is very efficient compared using other controllers.

3.2.5 PIC16F877 Microcontroller

Figure 3.4 shows the pin layout for the 40 pins PIC16F877 which extend the features in PIC16F84.

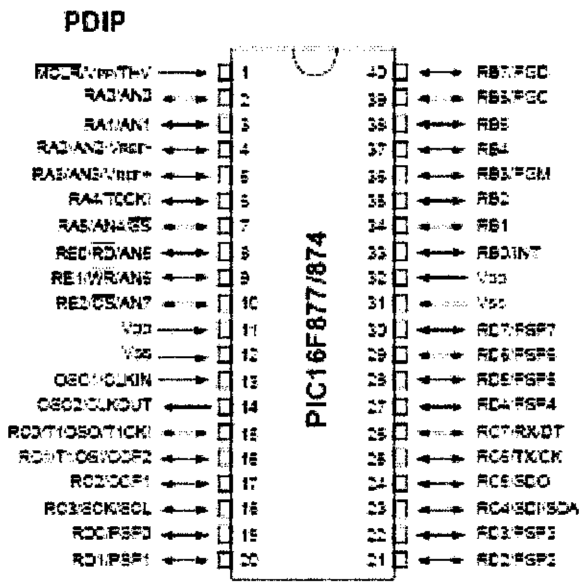
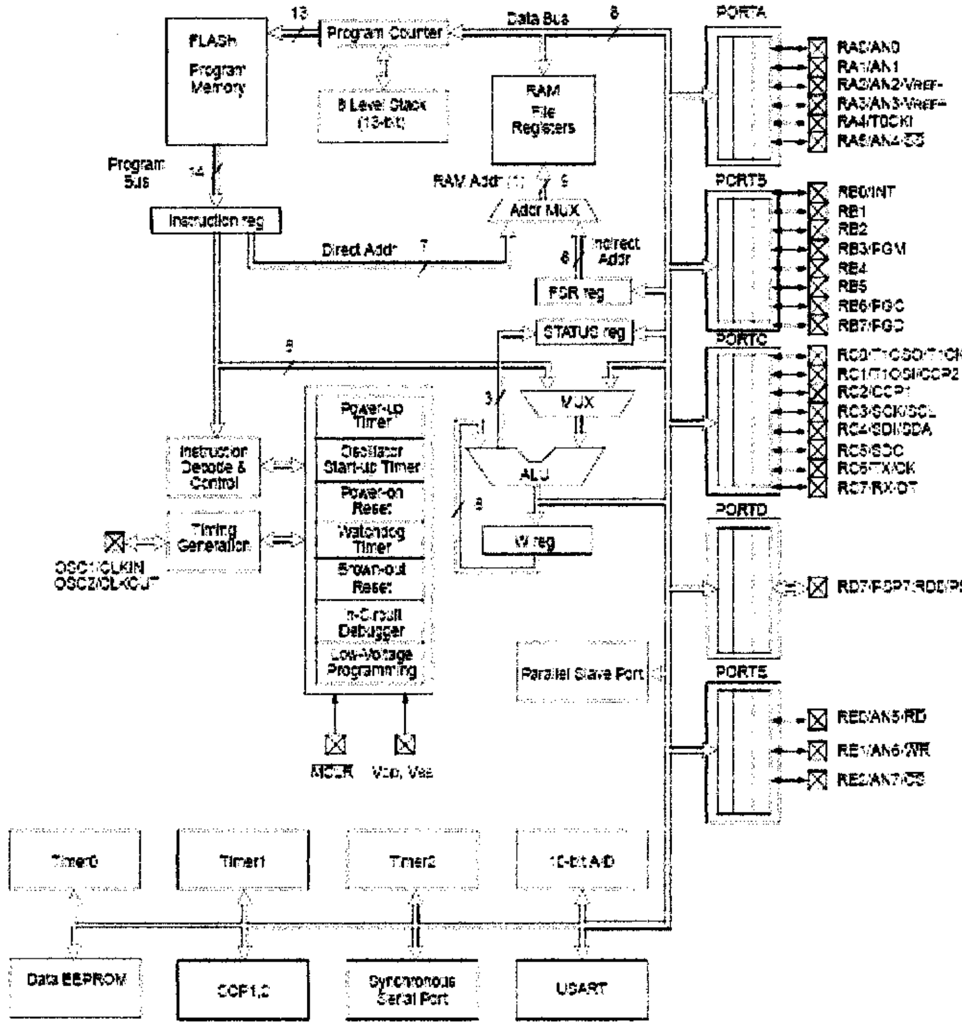


Figure 3.4: PIC16F877 pin layout [9]



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

Figure 3.5: PIC16F877 block diagram [9]

Figure 3.5 above shows the connection within the PIC16F877 in the block diagram.

Features of PIC16F877 are as follows:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches with two cycle
- Operating speed: DC – 20 MHz clock input
- 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
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on reset (POR)
- Power-up time (PWRT) and Oscillator Start-up Time (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: 25mA
- Commercial and industrial temperature ranges
- Low power consumption:
    - < 2 mA typical @ 5V, 4 MHz
    - 20 microA typical @ 3V, 32 kHz
    - < 1 microA typical standby current

3.2.6 Stepper Motor

Motors convert electrical energy into mechanical energy. A stepper motor converts electrical pulses into specific rotational movements. The movement created by each pulse is precise and repeatable, which is why stepper motors are so effective for positioning applications.

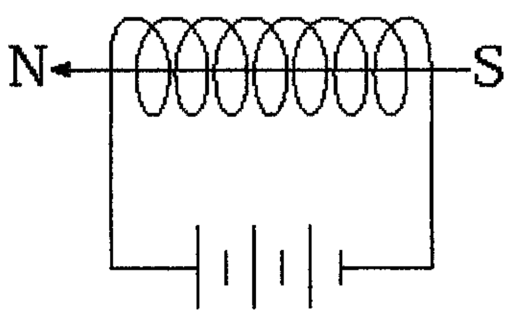


Figure 3.6: Stepper motor

Permanent Magnet stepper motors incorporate a permanent magnet rotor, coil windings and magnetically conductive stators. Energizing a coil winding creates an electromagnetic field with a North and South Pole as shown in figure 3.6. The stator carries the magnetic field which causes the rotor to align itself with the magnetic field. The magnetic field can be altered by sequentially energizing or "stepping" the stator coils which generates rotary motion.

For a typical step sequence for a two phase motor, during Step 1, phase A of a two phase stator is energized. This magnetically locks the rotor in the position shown, since unlike poles attract. When phase A is turned off and phase B is turned on, the rotor rotates 90° clockwise. In Step 3, phase B is turned off and phase A is turned on but with the polarity reversed from Step 1, this causes another 90° rotation. In Step 4, phase A is turned off and phase B is turned on, with polarity reversed from Step 2. Repeating this sequence causes the rotor to rotate clockwise in 90° steps.

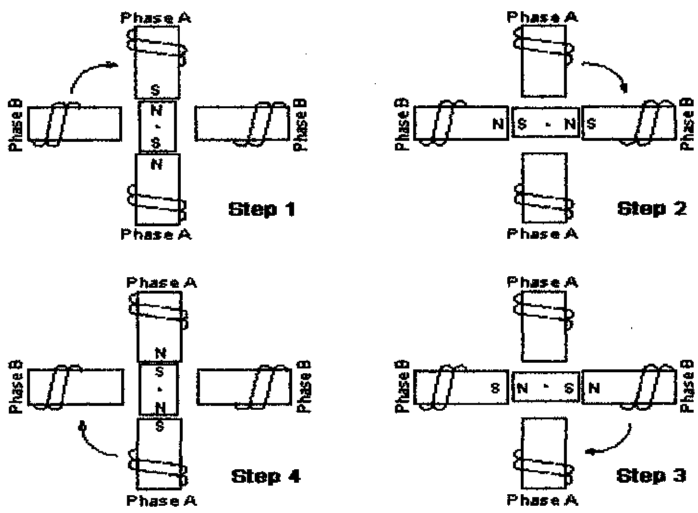


Figure 3.7: One phase 'on' stepping sequence for two phase motor

The stepping sequence illustrated in figure 3.7 is called "one phase on" stepping. A more common method of stepping is "two phase on" where both phases of the motor are always energized. However, only the polarity of one phase is switched at a time. With two phases on stepping the rotor aligns itself between the "average" north and "average" south magnetic poles. Since both phases are always on, this method gives 41.4% more torque than "one phase on" stepping, with equivalent power input.

Stepper motors require some external electrical components in order to run. These components typically include a power supply, logic sequencer, switching components and a clock pulse source to determine the step rate. Stepper motors are devices that rotate a precise number of degrees for each "step" applied as opposed to regular motors, which simply rotates continuously when power is applied.

3.2.7 Implement All Features

When the circuit and software have completed, all the features which are the transmitter, receivers, motor, PIC and camera being put together where the circuits had been placed in a box, while the sensor and camera were bounded onto the circuit box.

3.2.8 Testing and Troubleshooting

The final part which is the testing and trouble shooting the prototype has to be done in order to make sure that the prototype worked properly according to the requirement. The results will be discussed in Chapter 4.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Circuit Development

The circuit diagram for this project is based on the hobby kit. The hardware had been implemented and so far the transmitter and receiver are working very well. The hobby kits have been modified to suit the requirement of this project whereby two receivers are connected with one transmitter which located on the left and right of the transmitter. The output of both receivers will be compared using LM358 operational amplifier act as a comparator and into the microcontroller. Then, the microcontroller will direct the stepper motor to rotate according to the comparison by the receivers. When any receiver detects any movement, the signal by both receiver will be compared and if the right receiver input signal is higher than the left receiver, the stepper motor will rotate to the right until the difference between both receiver is very small which is set to a certain limit. The hardware however is still under development and yet to be tested once all parts have been completed. For the time being, the ultrasonic transmitter and receivers are working very well and have been tested using a LED which lights up when there is movement and also using a multi meter where the voltage at the receiver changes when it detects movement.

For the circuit configuration, it is first tested using one transmitter and one receiver. Figure 4.1 below shows the circuit diagram of the first circuit.

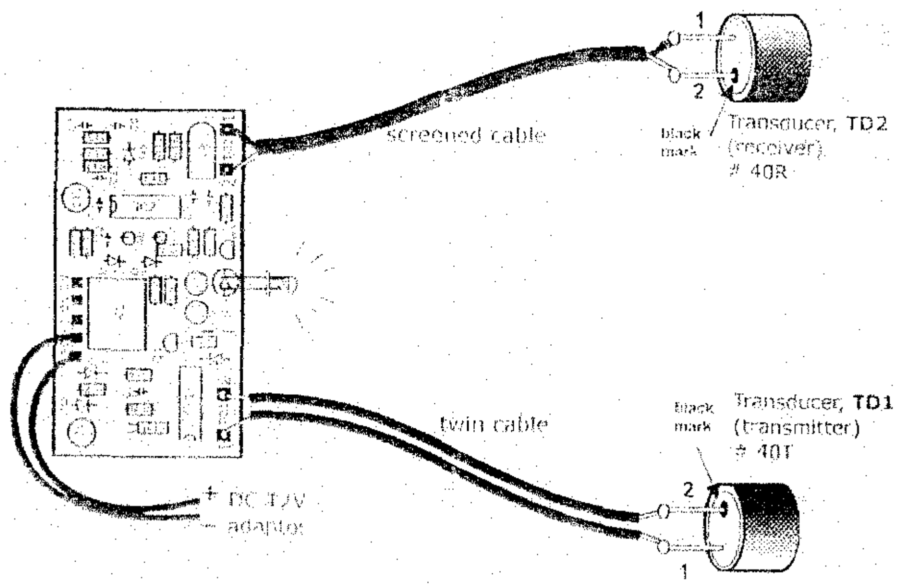


Figure 4.1: Circuit diagram of the ultrasonic sensor

To have a better image of the circuit, figure 4.2 shows the block diagram of the circuit of transmitter and receiver of ultrasonic sensor.

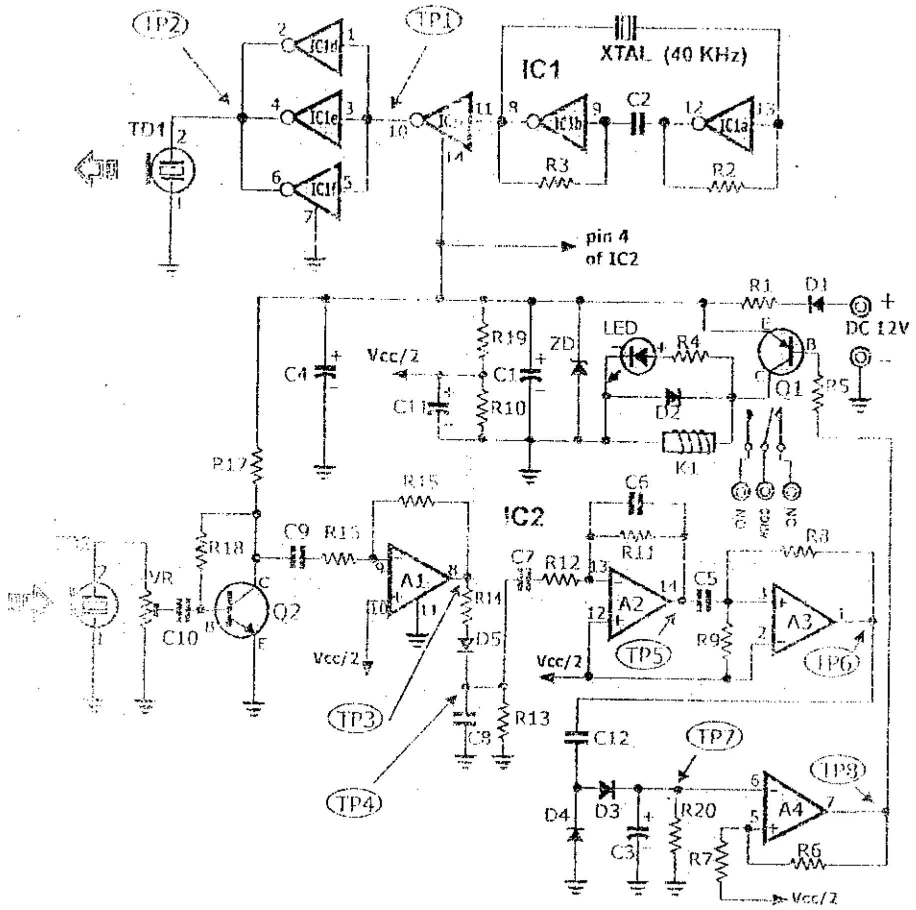


Figure 4.2: Block diagram of ultrasonic transmitter and receiver

As for the result, oscilloscope is used to check the pattern of signal dissipated which taken at 8 points. By putting the probe to the point named TP 1 to TP 8, the signal is as figures follows:

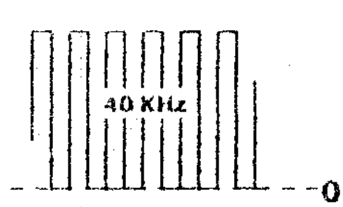


Figure 4.3: Output signal from crystal oscillator at point TP 1

The output signal produced by the crystal is 40 kHz as in figure 4.3, where it suits the ultrasonic frequency.

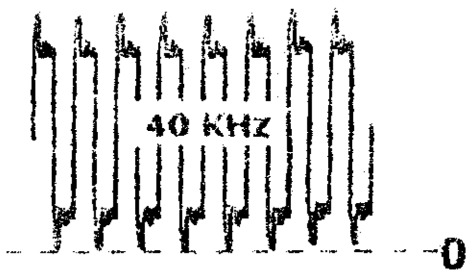


Figure 4.4: Transducer driving signal at point TP 2

At point TP 2, the signal is as in figure 4.4 where it shows the transducer driving signal before it is transmitted to the surroundings.

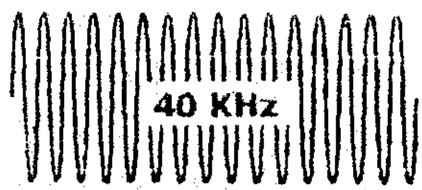


Figure 4.5: Receiving signal at point TP 3 when no moving object

From the detection circuit, the signal received by the receiver is then amplified by an amplifier. When there is no moving object detected, the signal is tapped at the point TP 3 and the signal is shown in figure 4.5 where the amplitude is constant. If there is a present of moving objects, the signal experienced obstacles and the signal is wrapped in the envelope signal with changing amplitudes as shown in figure 4.6.

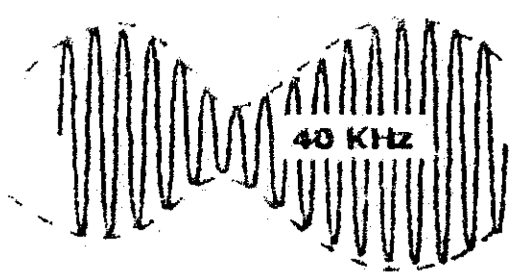
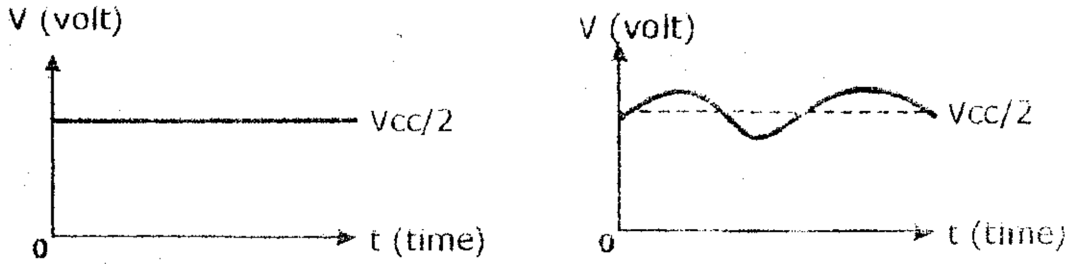


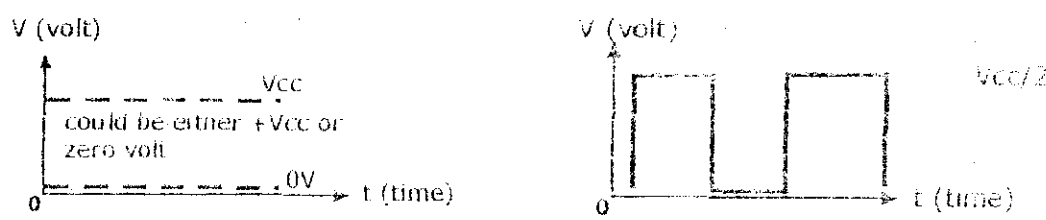
Figure 4.6: The output signal when detect moving object at point TP 3

At point TP 4, the signal is converted into voltage by having components of resistors (R13 and R14), capacitor (C8) and diode (D5) as frequency of envelope signal is directly proportional with the speed. The comparison between voltages for no moving object and with moving object detected is as figure 4.7.



No moving object Moving object detected

Figure 4.7: Comparisons of voltages when moving objects detected at point TP 4

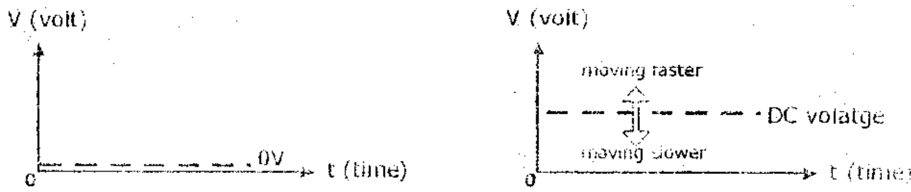


No moving object Moving object detected

Figure 4.8: Comparison of square wave when moving objects detected at point TP 6

From point TP 4, the signal is amplified by amplifier A2, and then the signal is converted into square ware by A3 a quad operational amplifier as shown in figure 4.8.

The envelope signal is then converted into DC voltage by the circuit which includes a 1M ohm resistor, 1uF and 0.1uF capacitors and two 1N 4148 switching diodes. The output signal is tapped at point TP 7 and the voltage signal is as shown in figure 4.9. When there is no moving object, the voltage will be 0V but once it detected moving objects, the voltage will increase according to the movement of the objects. If the object move faster, the voltage will be higher but if the object moves slower, the voltage will be smaller.



No moving object

Moving object detected

Figure 4.9: Comparison of voltages when moving object is detected

The same receiver circuit is used for the second receiver and the voltage difference will be compared between both signals. The output of the signal is fed to the PIC 16F877 microcontroller where it will give instructions to the stepper motor whether to turn left (when voltage of left receiver is higher than the right receiver) or turn right (when voltage of right receiver is higher than the left receiver) or remain still (when the voltage difference between both receivers is very small).

4.2 Hardware Configuration

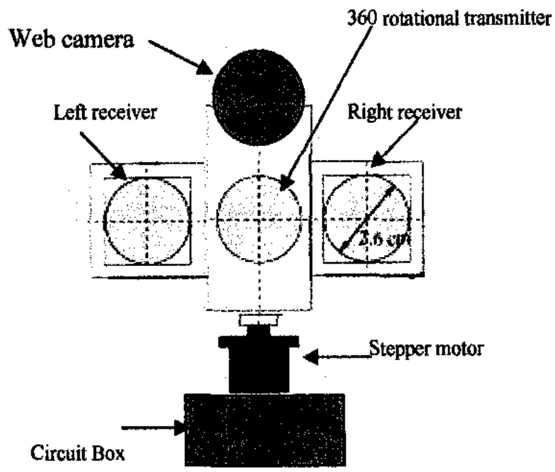


Figure 4.10: Hardware platform for the project

For the hardware configuration, figure 4.10 shows the basic hardware which will be implemented in the final stage of implementing all features. From the figure above, the right and left receivers are connected directly to the transmitter on both sides in order to make it easier for the receivers to detect the ultrasonic signal thus give direction to the stepper motor whether to turn left, right or remain at it own position accordingly. Below the motor is the circuitry compartment where all the circuits are placed. The features may be expanded if the time and budget still do not exceed the allocation given.

Since all the methodologies have been implemented and the circuits have been tested. The PIC programming and the hardware also have been successfully completed. The prototype of target tracking system using ultrasonic is working very well which meets all the requirements and objectives set earlier in this project. The prototype of target tracking system is as figure 4.11 below.

Figure 4.11: The prototype of target tracking system using ultrasonic sensor

4.3 Comparison between Normal CCTV and Prototype

The *normal CCTV* has some disadvantages which can be overcome by using the target tracking system which are:

Expensive: the normal CCTV usually costs around RM1000 just for the camera without taking into account the installation cost

Difficult to install: the normal CCTV needs experts to install the CCTV system which includes wiring of the camera and the power supply, the television and the installation can cost 30 to 50 percent of the overall price of the CCTV system

Non-clear image: basically, there are two types of CCTV which are the static CCTV and the rotating CCTV. The static CCTV usually is installed at the edge of a room where the image will become unclear when it is zoom in to focus on an object. If the CCTV is installed to focus on a specific place, the space covered will be very narrow and the whole view cannot be seen. For the rotating CCTV, it rotates in 360 degrees continuously and this creates blind spots and not efficient. The other disadvantage of both static and rotating CCTV is they are installed on the ceiling and it provides image from above. It will be hard to recognize a person when the person is wearing hat or anything covering the head.

With proper installation, all the disadvantages as discussed above can be overcome by using target tracking system using ultrasonic sensor.

Cheap: target tracking system is very cheap compared to the normal CCTV where it cost around RM100 only which is only 10 percent from the amount of the normal CCTV.

Easy to install: with the small size of 9.5cm x 8.5cm x 15.5cm, it can suit almost everywhere appropriate to target and track movements without any fixed wiring required. Equipped with USB cable, the prototype can be used with any computer which support plug and play for USB.

Clear image: as the prototype is movable, with proper installation, it can provide clear image even using standard quality camera (1.3 mega pixels). It is good to place it on the table or about the height of a person for a straight image caption of the face for face recognition.

Figure 4.12: CCTV caption

Figure 4.13: Prototype caption (1)

The CCTV caption is shown in figure 4.12 where the CCTV is installed on the ceiling to monitor the entrance. In figure 4.13, it is the caption from the prototype which was placed on the table to monitor the entrance as well. From the two captions, the image of the person is clearer by using the prototype as the face can be seen compared to the CCTV caption. The prototype provides not only clearer view but it detects the person's movement from the beginning he enters the room and tracks the movement of the person.

Figure 4.14: Prototype caption (2)

In the figure 4.14, it is the continuation of the caption from the prototype. In this figure, the person's activity can be captured as well. The prototype can monitor not only the entrance, but it tracks the movement to provide wider view of the place and thus minimize the blind spots.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project uses ultrasonic sensors to detect and track moving object. It uses a transmitter and two receivers bound on both sides of the transmitter. The difference in voltage received by the receivers will give signals to the PIC to instruct the stepper motor to rotate according to the difference voltage sensed by the receivers. Once the voltage difference is very small, the motor will stop rotating to give indication that the moving object is now stationary. This project is very cost effective where it uses the cheapest circuit design. It is beneficial to control and reduces crime and specially designed to expand the usage of technology of ultrasonic sensors which has never been implemented in security system. The working prototype of a target tracking system has been successfully produced and can be used in security risk areas which can detect and track one moving object within a radius of 3 meters and hence help to reduce the number of crime rate in Malaysia.

5.2 Recommendation

The project had been very successful where it manages to reach the requirements set in the planning stage. However, in future work, some modification can be made to accommodate improvement to this project. Some of the recommendations which can be done are:

Upgrading the camera with zoom in effect

For better image, zoom in effect can be introduced in this prototype. The current camera used for the prototype is a web cam with resolution of 1.3M pixel. If the camera can zoom in and out according to distance of the moving object, it can add up value to the prototype.

Expanding the range of tracking moving object

The tracking range should be expanded to longer coverage for optimizing the usage of this prototype. The range of 3 meters is only suitable for small room. If the prototype need to be installed in a bigger room or outdoor, it is best to expand the range to 10 meters.

Increase the number of moving objects that can be detected

For more efficient prototype, increase in the number of moving object that can be detected is crucial. For the time being, the prototype can detect and track one moving object successfully. In the future, the number of moving objects which can be detected should be increased.

Liaise with image processing for image scanning

In order to boost up the technology application in the security system, the image taken from the prototype of target tracking system can be scanned using image processing. The scanned image will be sent through the criminal files to check whether the person doing the crime is a wanted criminal or not. By then, it is easier to catch loose criminals.

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APPENDICES

APPENDIX A

PROGRAM CODES

```
#include <16F877.h>
#include <stdio.h>

#fuses XT, NOWDT, NOPROTECT, NOBROWNOUT, NOPUT, NOLVP
#use delay(clock = 4000000)

#define V1 input(PIN_A0)
#define V2 input(PIN_A1)

void main()
{
	while(1==1)
	{
		if(V1<V2)
		{
			output_bit(PIN_D4,1);
			output_bit(PIN_D5,0);
			delay_us(10);

			setup_ccp1(CCP_PWM);
			set_pwm1_duty(75);
			break;
		}
		else if(V1>V2)
		{
			output_bit(PIN_D4,0);
			output_bit(PIN_D5,1);
			delay_us(10);

			setup_ccp1(CCP_PWM);
			set_pwm1_duty(75);
			break;
		}
```

```
            else if(V1==V2)
            {
                    output_bit(PIN_D4,0);
                    output_bit(PIN_D5,0);
                            delay_us(10);

                    setup_ccp1(CCP_PWM);
                    set_pwm1_duty(75);
            }
    }
}
```

APPENDIX B

PIC 16F87X DATASHEET

PIC16F87X

28/40-pin 8-Bit CMOS FLASH Microcontrollers

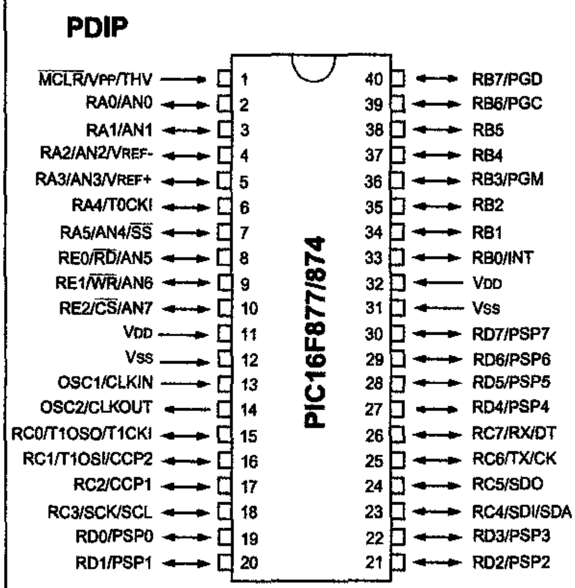
Devices Included in this Data Sheet:

- 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 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

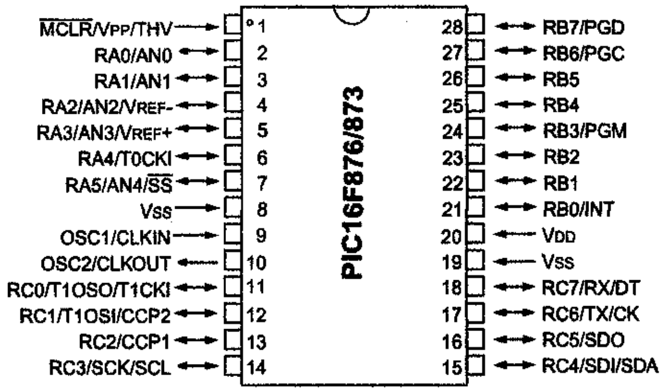


Peripheral Features:

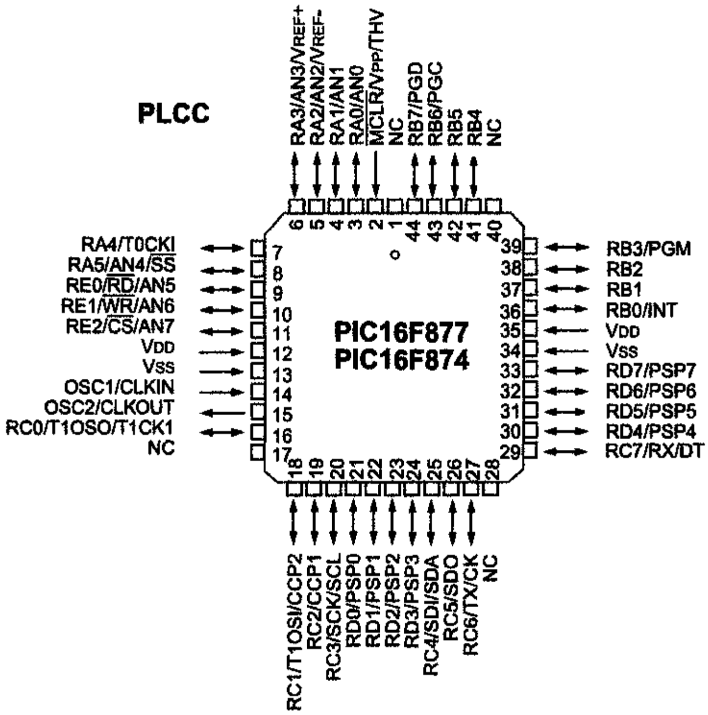
- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. 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)

Pin Diagrams

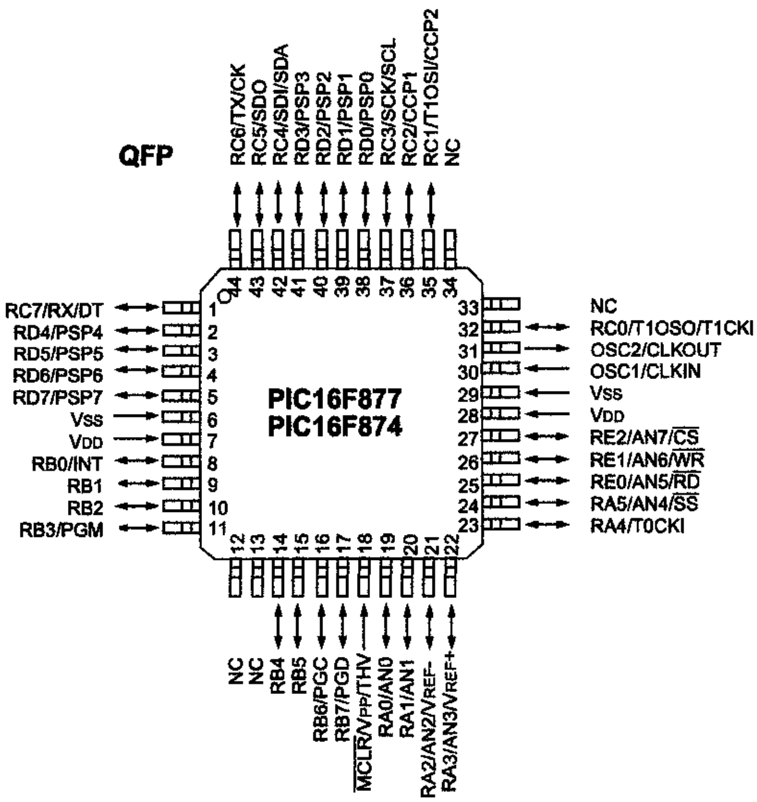
DIP, SOIC



PLCC



QFP



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

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Corrections to this Data Sheet

We constantly strive to improve the quality of all our products and documentation. We have spent a great deal of time to ensure that this document is correct. However, we realize that we may have missed a few things. If you find any information that is missing or appears in error, please:

- Fill out and mail in the reader response form in the back of this data sheet.
- E-mail us at webmaster@microchip.com.

We appreciate your assistance in making this a better document.

1.0 DEVICE OVERVIEW

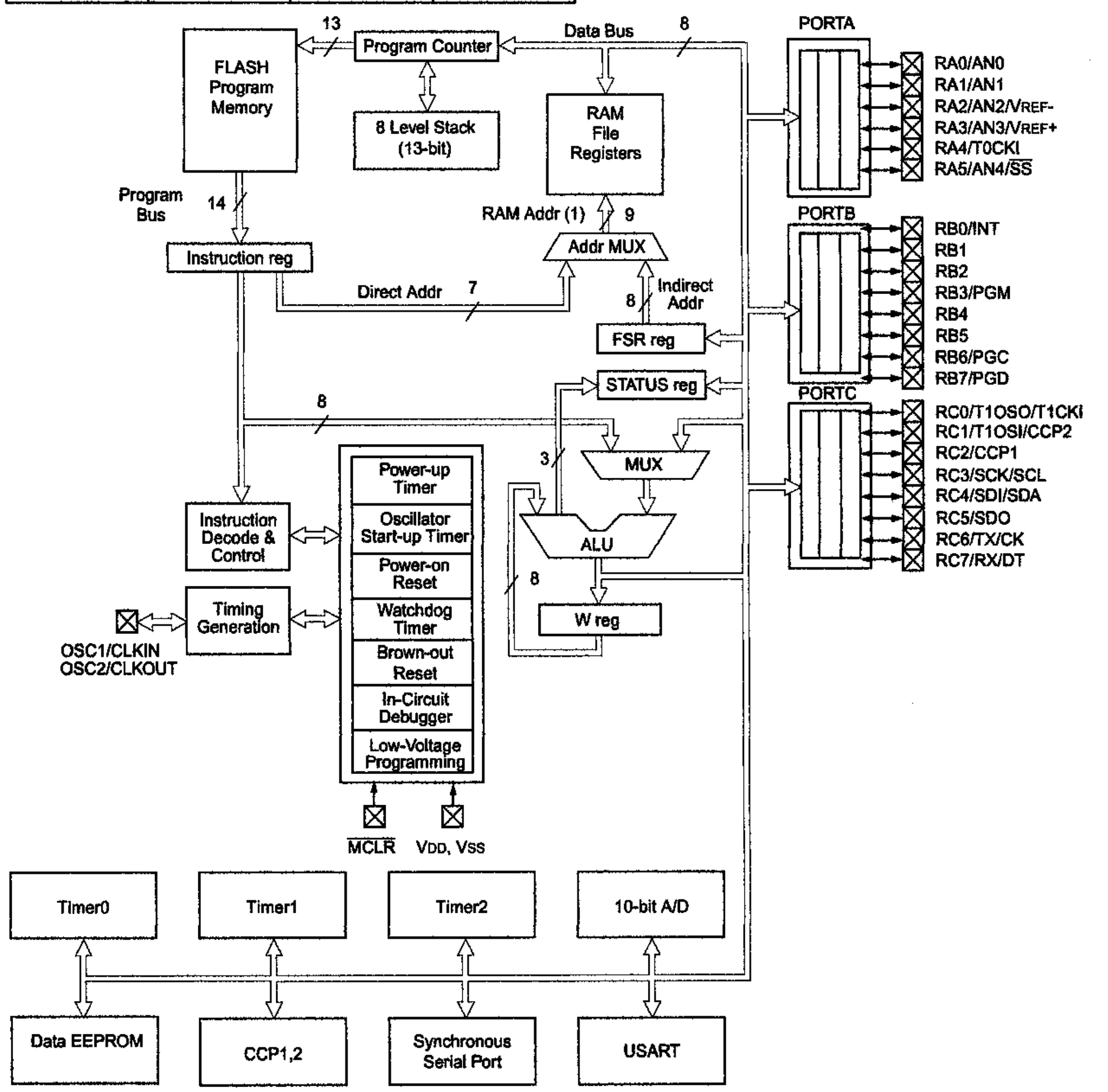
This document contains device-specific information. Additional information may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip website. The Reference Manual should be considered a complementary 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 28-pin devices do not have a Parallel Slave Port implemented.

The following two figures are device block diagrams 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



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