ALARM SYSTEM USING BODY DETECTOR

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BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **ALARM SYSTEM USING BODY DETECTOR**

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This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor Degree of Electrical Engineering (Electronics)

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Specially dedicated to my beloved family

To My Beloved Mother and Dad, My sister & My Sweet Little Brothers

Noor Din Bin Mansor
Nurawati Binti Yusof

Aishah Binti Noor Din
Mohamed Hashim Din Bin Noor Din
Mohamed Emir Hamzah Bin Noor Din

And those people who have guided and inspired me throughout my journey of education

Thank's For Everything…

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ABSTRACT

Nowadays, portable automatic intruder system has become very popular among security system. Body detector is a valuable technology tool that can be used to perform Alarm System Using Body Detector. Alarm system by using a body detector is an application for the smart alarm system because it relies only with the existence of electrical field that surrounds the human body. This alarm system adopts advanced RF oscillators matched with reliable software technology and advanced hardware circuitry. It integrates capacitance detection, network search, and automatic voice alarm. This system mainly uses capacitance detector, body intruding detection to transmit alarming signal to main unit. When signal is received, it processes it immediately, and then main unit will automatically give an alarm by the designed code. The idea behind this project is to solve the problem of traditional security method by using a non-portable alarm system due to excessive data transfer and complex hardware circuitry. Body detector security system makes all services that relate to information simpler, safer, cheaper and portable. In this project, a Microcontroller PIC16F877 will be used as an actuator of the system that will control the output system through a programming system. The system will be developed to control the system flow such as register data, delete data, and creating program flow to produce the output depends on the activation of body detector hardware circuitry. The PIC16F877 microcontroller will analyze and process the data and if the data has been registered in the system, the security application will work such as triggering the buzzer and LED.

ABSTRAK

Pada masa kini, sistem sekuriti yang boleh di bawa ke mana-mana menjadi semakin popular dan telah berkembang luas dalam sistem keselamatan. Body Detector merupakan satu teknologi yang amat berguna dan sesuai untuk membangunkan Alarm System Using Body Detector. Alarm System Using Body Detector merupakan sistem sekuriti yang efisien dan cekap kerana hanya menggunakan aruhan elektrik semulajadi yang terdapat persekitaran badan manusia. Sistem sekuriti ini mengadaptasikan osilasi frekuensi radio yang dipadankan dengan teknologi perisian dan perkakasan litar yang hebat. Sistem ini melibatkan pengenalpastian kapasitan, pencarian rangkaian, dan sistem bunyi automatik. Sistem ini juga menggunakan keutamaan di dalam pengenalpastian kapasitan, pengenal pastian pencerobohan dan untuk menghantar signal kepada unit utama. Apabila signal diterima, ianya akan diproses serta merta dan unit utama secara automatik akan mengeluarkan bunyi yang bergantung kepada sistem kod yang direka khas bagi melengkapkan projek ini. Idea di sebalik projek ini adalah untuk merungkaikan masalah yang berlaku kepada sistem sekuriti sebelum ini dimana sistem sekuriti yang lama tidak mampu untuk dibawa ke mana-mana kerana penghantaran data berlebihan memerlukan punca volt yang tinggi dan litar yang kompleks. Body Detector memudahkan semua servis yang berkaitan dengan kemudahan, keselamatan, dan kemurahan. Di dalam projek ini, microcontroller PIC 16F877 digunakan untuk mengawal sistem atur keluaran melalui sistem program. Microcontroller PIC 16F877 akan menganalisa dan memproses data dan sekiranya data telah didaftarkan di dalam sistem, maka aplikasi sistem akan berfungsi dan mengaktifkan LED dan penggera.

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LIST OF ABBREVIATIONS

A.C.	Alternating Current
ADC	Analog to Digital converter
BPS	Bit per second
CCTV	Closed Circuit Television
CMOS	Complementary metal–oxide–semiconductor
Cm^2	Centimeter square
CPU	Central processing unit
DAC	Digital to Analog converter
EPC	Electronic product code
EPROM	Erasable Programmable Read-Only Memory
H.F.O	High Frequency Oscillation
.HEX	Hexadecimal Files
I/O	Input / Output
LC	Inductance - Capacitance
L.E.D	Light Emitting Diode
L.F.O	Low Frequency Oscillation
MCU	Microcontroller Unit
PIC	Programmable Interface Controller
RF	Radio Frequency
RFID	Radio Frequency Identification
RISC	Reduced Instruction Set Computing
OSC	Oscillation
RC	Resistance - Capacitance
MAC	Medium access control
RAM	Random access memory
ROM	Read only memory
WWW	World wide web

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Alarm system implies an emergency procedure that should be carried out while body detector is a device that can detect the existence of human body for a certain wide range of area. Alarm system by using a body detector is an application for the smart alarm system because it relies only with the existence of electrical field that surrounds the human body. Safety alarms are used widely nowadays in order to gain safety and precautions for communities and individuals. In new construction, wireless systems may be more economical but it is still on high cost and need experts to develop due to its complexity. This alarm system adopts advanced RF oscillators matched with reliable software technology and advanced hardware circuitry. It integrates capacitance detection, network search, and automatic voice alarm. The reliable components combination from resistance, capacitance, and digital coding technology are also used. This system mainly uses capacitance detector, body intruding detection to transmit alarming signal to main unit. When signal is received, it processes it immediately, and then main unit will automatically give an alarm by the designed code.

Every living human body is surrounded by an electric field, which may potentially be detected at a few meters' distance. Even if this can only be detected at a distance of a few centimeters (as opposed to millimeters), the applications are legion. The phenomenon of capacitance is entirely dependent on the existence of electric fields. If, therefore, a human body should approach the positive plate of a capacitor, the body's electric field will cause the value of the capacitor to rise. In the Body Detector circuit, this is detected by means of an RC (resistance-capacitance) oscillator. As the value of C rises, so the frequency of the oscillator drops. All that remains is to detect this drop in frequency to obtain some interesting results. While in theory its operation is dependent on the electric field which surrounds the human body, in effect it would seem that an invisible field surrounds the sensor – somewhat like the "invisible" defense shields. It would appear, therefore, that as a human hand (for instance) enters this invisible field, an alarm is triggered.

In this final project, the main objective is to create a system that would detect human body existence using body detector. Body detector using alarm system is a very valuable technology tool since there is no use of any giant padlock, heavy chain or security guard service anymore in the system. The other objective is to develop portable alarm system application by enhancing the designation of hardware and software. Alarm system using Body Detector offers strategic advantages for security dependence because the input stored in the capacitance detection circuit through the microcontroller can be protected against undesired accessed trigger and any manipulation.

This is really important to make sure the area is safe and to avoid strangers from gain access in the area. In this project Alarm System Using Body Detector provide an effective security system by having a sensor that is completely vandal-proof and tamper-proof. One could not come near it with a pair of clippers or a similar instrument because it is immune to alternating current (ac) fields and it will also detect body presence on the other side of variety of materials including the insulators.

Generally, the system will consist of a body detector as an input sensor, a PIC16F877 microcontroller that performs as a serial interface to accomplish effective surveillance application and a circuitry of the alarm system applications. The body detector contains an astable oscillator (IC1a) and a non-retrigerable monostable (IC1b). The PIC16F877 circuitry consists of power supply, frequency gain, and programmer function as drivers for communication interface. While the alarm system made from only passive elements such as capacitors, inductors, resistors, LEDs and buzzer that will performed when access is denied.

Body Detector works based on a system that relies on capacitance value surrounding human body and PIC16F877 microcontroller acts as an activator of the body detector input and PicBasic programming creates the flows of the whole operation of alarm application. In security field, Alarm System Using Body Detector will be more secured than the other personal alarm system. It offers varieties of convenience such as it can be a portable alarm system, can demand varies of distance of body detector could function and does not require any maintenance.

This final project is divided into 3 main sections:-

(1) Electronic design consists of Body Detector circuitry, PIC16F877 microcontroller design and alarm security system application.
(2) Develop Software to verify the input and activate the flows of alarm applications.
(3) Mechanical design consists of body detector casing model.

1.2 OBJECTIVES

1.2.1 To create a system that would detect human body existence using body detector.

Current security application requires human for manual surveillance either using CCTV or depend on security guards. Body detector has the potential to eliminate human intervention. The advantages of develop a body detector alarm system is reduce labor costs, reduced costs, fewer errors and increased the building simplicity security.

1.2.2 To develop portable alarm system application by enhancing the designation of hardware and software.

Modern alarm system does not have the ability to perform in a state of portable. With body detector, the application can be portable and we able to have it functioned everywhere we desired. This is because body detector can be operates in many modes.

1.2.3 To develop a system that can verify and activate the flows of alarm system application using PIC16F877 microcontroller.

The PIC16F877 CPU is optimized for low power consumption and high performance operation at bus frequencies up to 4 MHz. In many applications, the PIC16F877 provides a single chip solution with mask programmed ROM or user-programmable EPROM. By implementing PIC16F877, body detector act as an input to microcontroller while the microcontroller act as an activator for the sequence and flows of the alarm system applications.

1.3 SCOPE OF PROJECT

The scopes that need to be proposed for this project are:

1.3.1 To develop a system that could detect the existence of human the range between $1 < cm^2 < 30$.

1.3.2 To create the application of alarm system body detector and integrate the system by using PIC16F877 microcontroller.

1.4 PROBLEM STATEMENT

This project is focusing on the detection of human body existence and the creation in the application of alarm system. Yet, there are lots of problems with the previous alarm system.

1. Technologies produced alarm system that would probably be intelligent, but the capital to undergo the constructions is still on high cost and need experts to develop. But for alarm system using body detector, the only capital for undergo the construction is fully depends on the electrical fields around human body. By this means, body detector will functioned only with the existence of human body. Body detector circuitry is simple (consists of resistance capacitance elements) and low cost.

2. RFID, Bluetooth and wireless alarm system are not able enough to be portable kit and could not bring the alarm everywhere. By using body detector, sensor (example, metal sensor sheet of tin foil), this element could be a portable sensor and the sensitivity to trigger the body detection is high. By this means, elements in body detector can be adopted to be portable alarm system applications. It could be an alarm everywhere we desired.

3. The previous body detector circuitry have very high sensitivity for temperature rising. It is satisfactorily functioned in the temperature between 10°C - 25°C. But for this new development of body detector, it will function satisfactorily in the temperature between 20°C to 35°C.

1.5 THESIS OVERVIEW

This Alarm System Using Body Detector final thesis is a combination of 6 chapters that contains and elaborates specific topics such as the Introduction, Literature Review, Methodology, Hardware Design, Software Design, Result, Discussion, Conclusion and Further Development that can be applied in this project.

Chapter 1 basically is an introduction of the project. In this chapter, the main idea about the background and objectives of the project will be discussed. The full design and basic concept of the project will be focused in this chapter. The overview of the entire project also will be discussed in this chapter to show proper development of the project.

Chapter 2 will be discussed about the literature reviews of this project based on journals and other references.

Chapter 3 will be focused on methodologies for the development of alarm system body detector. This includes the future project development that can be added in this project.

Chapter 4 will be focused on hardware design of the Alarm System using Body Detector. This chapter included three main sections. The first section will be focused on the circuitry on body detector, while the second section will be stressed on the microcontroller design which is about the PIC16F877 design. The other section is about the implementation of applications design. In electronics design, we will discuss about fabricating the body detector and microcontroller board.

Chapter 5 will be discussed about the software development of the PIC16F877 microcontroller board. In this section, software development such as software compiler, software design will be discussed further. The difference between ordinary Microcontroller and PIC family microcontroller also will be described in this chapter.

Chapter 6 discusses all the results obtained and the limitation of the project. All discussions are concentrating on the result and performance of Alarm System Using Body Detector. This chapter also discusses the problem and the recommendation for this project.

Chapter 7 discusses the conclusion and further development of the project. This chapter also discusses about complexity of integrating new technology to develop a complete working system and overall alarm system using body detector for the future development.

CHAPTER 2

LITERATURE REVIEW

2.1 An Overview

A **human body detector** comprising: a capacitance-type sensor that a human body contacts or approaches, the capacitance-type sensor including a sensor resonance circuit and a wave detector circuit; detection means for receiving an output of the capacitance-type sensor, and distinguishing between the human body from a raindrop and detecting only the human body based on a change in the output within a predetermined time, the detection means including a band-pass filter, the band-pass filter including a differentiator, a high-pass filter and a comparator; and wherein the sensor resonance circuit has a sensor electrode supplied with a constant frequency voltage and outputs a resonance voltage integrated the constant frequency voltage with respect to a capacitance of an object that contacts to the sensor electrode, the wave detector circuit outputs a wave detection voltage obtained through wave detection and conversion of the resonance voltage, and the differentiator differentiates the wave detection voltage with respect to time to acquire the changing rate.

In a human body detector, a wave-detection circuit for detecting waves of a resonance voltage is connected to a sensor resonance circuit that varies a constant frequency voltage in accordance with a change in the capacitance of a sensor electrode. The wave-detection circuit is connected to a differentiator that acquires a changing rate by differentiating the wave-detection voltage with respect to time, and allows a voltage to pass if the changing rate of the voltage is greater than or equal to a predetermined value. The differentiator is connected to a high-pass filter that allows passage of a voltage whose changing rate is greater than or equal to a second predetermined value. The high-pass filter is connected to a comparator whose non-inversion input terminal is connected to a power source that applies there to a reference voltage.

While **alarm system** (Figure 2.1) is a sound or visual signal which indicates an error condition. The terms alarm and alert are often used synonymously. It is a sudden fear caused by the realization of danger and usually gives warning of existing or approaching danger. For an electrical, electronic, or mechanical device that serves to warn of danger by means of a sound or signal, the sounding mechanism of an alarm clock is applied. In alarm system using body detector, it seems that this will be the best and possible applications. This could include safety switch (which would render an entire area a safety zone, this could shut down dangerous machinery, or child-proof certain areas), a touch sensor (trigger the alarm when items is touched), and also a tamper alarm.

Figure 2.1: Alarm system applications

A **microcontroller (µC)** is a computer-on-a-chip. It is a type of microprocessor emphasizing high integration, low power consumption, self-sufficiency and cost-effectiveness. It is a highly integrated chip that contains all the components comprising a controller. Typically this includes a CPU, RAM, some form of ROM, I/O ports, and timers. Unlike a general-purpose computer, which also includes all of these components, a microcontroller is designed for a very specific task -- to control a particular system. As a result, the parts can be simplified and reduced, which cuts down on production costs. Microcontrollers are sometimes called embedded microcontrollers, which just mean that they are part of an embedded system -- that is, one part of a larger device or system. Microcontroller will be the output from body detector and will be programmed with specific assembly language. Thus the operation of application is fully depending with the instruction programming.

2.2 Body Detector

Body Detector is a device that functioned by detecting human body existence which is in the area of body detector located. Body detector is detected by means of RC oscillator. Body detector relies on the fact that the human body itself possessed a fairly large order of capacitance to the ground (earth) and that if such a body approaches the positive plate of a given capacitor, its value will rise. Then, one could find a means to detect such an increase in capacitance, one means of detecting the presence of a human body. Electronic oscillators are often designed around an LC tank circuit, a tuned circuit formed with an inductor and a capacitor. But use of an inductor is not a requirement. Instead, the tuned circuit can be built using just resistors and capacitors. Such an oscillator is referred to as an RC oscillator. In the body detector circuit described here, this is detected by means of an RC (resistance-capacitance) oscillator. As the value of C rises, so the frequency of the oscillator drops. All that remains is to detect this drop in frequency to obtain some very interesting results.

Due to its high sensitivity and good stability, the body detector may be attached to a wide variety of metal objects (in the process sensitizing the entire object concerned. Although body detector is dependant on the electric field which surrounds the human body, in effect it acts as though an invisible field were created around the object concerned. From practical point of view, the sensor may include any object from size of a pin to 30kg in weight. However, the greater the weight metal sensor, the less the sensitivity of the circuit, the more critical the tuning and the more it becomes susceptible to temperature variations especially. If attached to lighter metal objects (sheet of tin foils), the body detector may be tuned to detect a person presence up to 50 cm away. At several centimeters' distance, the circuit is sufficiently stable to avoid spurious triggering over a wide temperature range. Modern proximity sensor will seldom detect a human body at more than a few millimeters' distance. Besides, the fact that some applications do not need a greater range because it is difficult to achieve greater range sensitivity with any reliability. In order to achieve greater range, Alarm System Using Body Detector need to overcome these challenges:

i) Environmental variations which affect the stability of the circuit. The bodies electrical is describe as extremely weak, and the body's capacitance at a small distance from a sensor is typically measured in fractions of a pico Farad. Therefore, the circuit need exceedingly sensitive.
ii) To find a means of reliably picking up small shifts in frequency as a body approaches, and to incorporate these in the circuit in a user-friendly way.

One of the advantages of the body detector is that the sensor is potentially completely vandal-proof and temper-proof. This means we could not come near it with a pair of clippers or similar instruments, let alone fingers. It is immune a.c. fields and it will also detect body presence on the other side of a variety of materials including insulators.

The body detector will work satisfactorily over a wide range of conditions. But my project which is Alarm System Using Body Detector is designed to perform to its best potential under the following circumstances:

iii) Over a modest temperature range (20°C to 35°C)
iv) Using relatively lightweight sensor – up to a kilogram (ideal)
v) Over longer periods (days at a time rather than minutes or hour)
vi) Multiple applications which require the unit or sensor to be moved

2.3 **PIC 16F877 microcontroller**

2.3.1 An Overview

The **PIC** (Programmable Interface Controller) line of microcontrollers was originally developed by the semiconductor division of General Instruments Inc (Figure 2.2). The first PIC's were a major improvement over existing microcontroller because they were a programmable, high output current, input/output controller built around a RISC (Reduced Instruction Set Code) architecture. The first PICs ran efficiently at one instruction per internal clock cycle, and the clock cycle was derived from the oscillator divided by 4. Early PICs could run with a high oscillator frequency of 20 MHz. This made them relatively fast for an 8-bit microcontroller, but their main feature was 20 mA of source and sink current capability on each I/O (Input/Output) pin. Typical micros of the time were advertising high I/O currents of only 1 milliampere (mA) source and 1.6 mA sink.

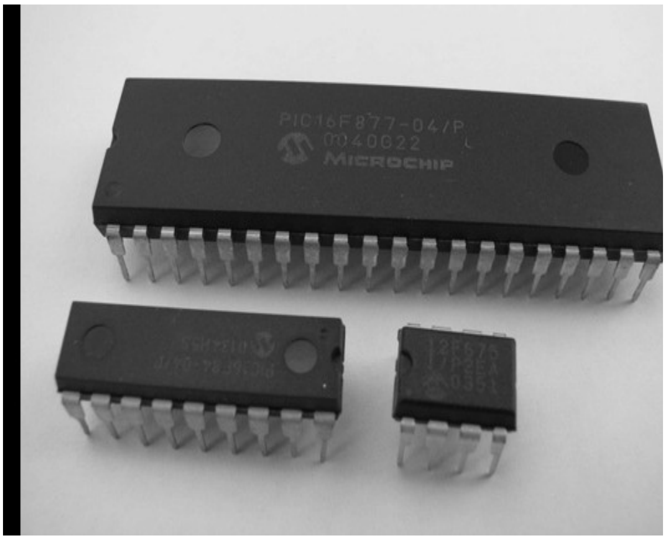


Figure 2.2: PIC microconrollers

PIC16F8X provides the EEPROM and flash. They have all the features of the base 14-bit core group which are interrupts, 13 I/O, one 8-bit timer, 0.5k or 1k of code space as EEPROM or flash and 36 or 68 bytes of RAM. Unique to these devices is the 64 bytes of EEPROM data memory. This data will stay even when power is removed so it's great for storing calibration or variable data to be used when the program starts again. They are very handy for development because they can be programmed over and over again without ever leaving the circuit while 16F87X have flash program memory so they can be reprogrammed over and over again. They are built to be identical to the 16C7X family with some data memory and program memory updates. They offer 22 to 33 I/O, three timers and up to 8k of program memory. They have all the special functions the 16C6X and 16C7X parts have as mentioned earlier. All the projects in this book will be built around the 16F876 because it is flash reprogrammable, has A/D, and has all the other PIC features. It also offers the option to build a bootloader inside. A bootloader allows you to program the part from a serial port without any special programmer circuitry.

2.3.2 PIC16F877 microcontroller implementation

Regarding this project, several reviews were made. One of the researches made is about the brain of the Alarm System using Body Detector which is PIC 16F877 microcontroller. PIC 16F877 is general purpose microprocessor which has additional parts that allow them to control external devices. Basically, a microcontroller executes a user program which is loaded in its program memory.

The reason for using PIC 16F877 (Figure 2.3) is because of the general purpose microprocessor which has additional parts that allow them to control external devices. Basically, a microcontroller executes a user program which is loaded in its program memory.

Figure 2.3: PIC16F877 microcontroller development board

Instead of using the MC68HC11 or Intel 8051 microcontroller, PIC 16F877 type of microcontroller architecture is distinctively minimalist. PIC microcontroller is the name for the microchip microcontroller (MCU) family, consisting of a microprocessor, I/O ports, timer (s) and other internal, integrated hardware. It is characterized by the following features:

(i) Separate code and data spaces.
(ii) A small number of fixed length instructions.
(iii) Most instructions are single cycle execution (4 clock cycles), with single delay cycles upon branches and skips.
(iv) All RAM locations function as registers as both source and/or destination of math and other functions.
(v) A hardware stack for storing return addresses.
(vi) Data space mapped CPU, port, and peripheral registers.
(vii) The program counter is also mapped into the data space and writable (this is used to synthesize indirect jumps).

Unlike most other CPUs, there is no distinction between "memory" and "register" space because the ram serves the job of both memory and registers, and the ram is usually just referred to as the register file or simply as the registers. PIC microcontrollers have a very small set of instructions (only 35 instruction), leading some to consider them as RISC devices, however many salient features of RISC CPU's are not reflected in the PIC architecture. For examples:

(i) It does not have load-store architecture, as memory is directly referenced in arithmetic and logic operations.
(ii) It has a singleton working register, whereas most modern architectures have significantly more.

2.3.3 **PIC 16F877 Bootloaders**

Bootloader is a utility which reads a program from a communication channel writes it to program/data memory and executes it. It therefore allows the possibility for programs to be updated or changed at a later date without requiring special programming hardware. The implementation of a bootloader for a Microchip PIC processor (16F877), however, the same procedure could be applied to many other type of processors. Before any coding starts, we should first think about how things are going to be positioned in program memory. Since the bootloader needs control after reset, it will mean that it will need to use the reset vector. Since we want to make it easy to build bootloader compatible programs, it is best if the bootloader is positioned entirely at the start of memory, or, all at the end of memory. On mid-range PIC's, the regular interrupt vector is located at address 0x4. If the bootloader was going to be positioned entirely at the start of memory, it would then have to redirect the interrupt vector to the downloaded program. Since this would add complexity to the code and latency to the vector, we have decided to position the bootloader at the end of memory. We will still need the reset vector, however, so this will mean shifting the downloaded program's reset vector elsewhere.

As shown in Figure A 2.4, typically the reset vector contains instructions to jump into the main program. Because the bootloader needs the reset vector, we therefore must move the downloaded program's reset vector elsewhere. Figure B 2.4 shows how the reset vector now points to the bootloader code and the downloaded program's reset vector will be positioned to an address just before the bootloader.

How it works:

i) On reset the bootloader will take control and prompt the user to send a hex file. It will wait here (with count down) for a configurable number of seconds.

ii) If no hex file is sent, the bootloader will assume that no update is required and it will jump to the redirected reset vector which in turn will run the previously downloaded program. If no program has ever been downloaded, the redirected reset vector will simply contain a jump to the beginning of the bootloader and the whole process will start again.

iii) If a HEX file is sent to the bootloader within the count down period, it will start interpreting the data and writing it to program memory. The bootloader will look for addresses less than 0x4 (reset vector) and will instead write this elsewhere. It will also ignore addresses conflicting with those used by the bootloader, thus protecting it from being overwritten.

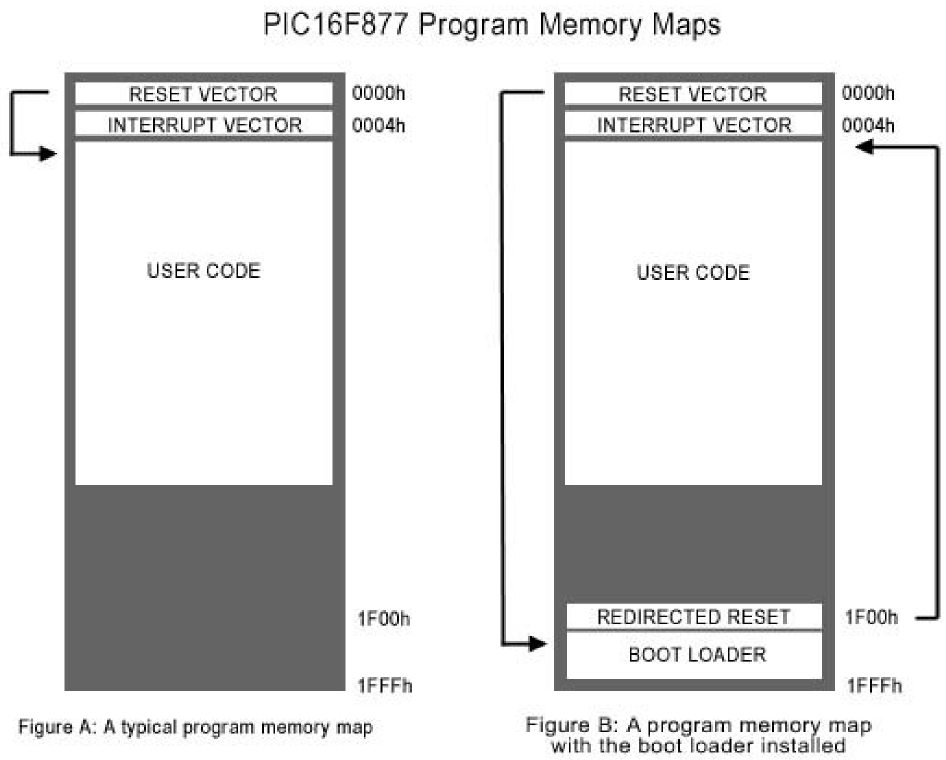


Figure 2.4: PIC 16F877 Botloaders

2.3.4 Memory Organization

There are three memory blocks in each of the PIC16F87X MCUs. The Program Memory and Data Memory (Figure 2.5) have separate buses so that concurrent access can occur. The PIC16F87X devices have a 13-bit program counter capable of addressing an 8K x 14 program memory space. The PIC16F877/876 devices have 8K x 14 words of FLASH program memory, and the PIC16F873/874 devices have 4K x 14. Accessing a location above the physically implemented address will cause a wraparound. The RESET vector is at 0000h and the interrupt vector is at 0004h.

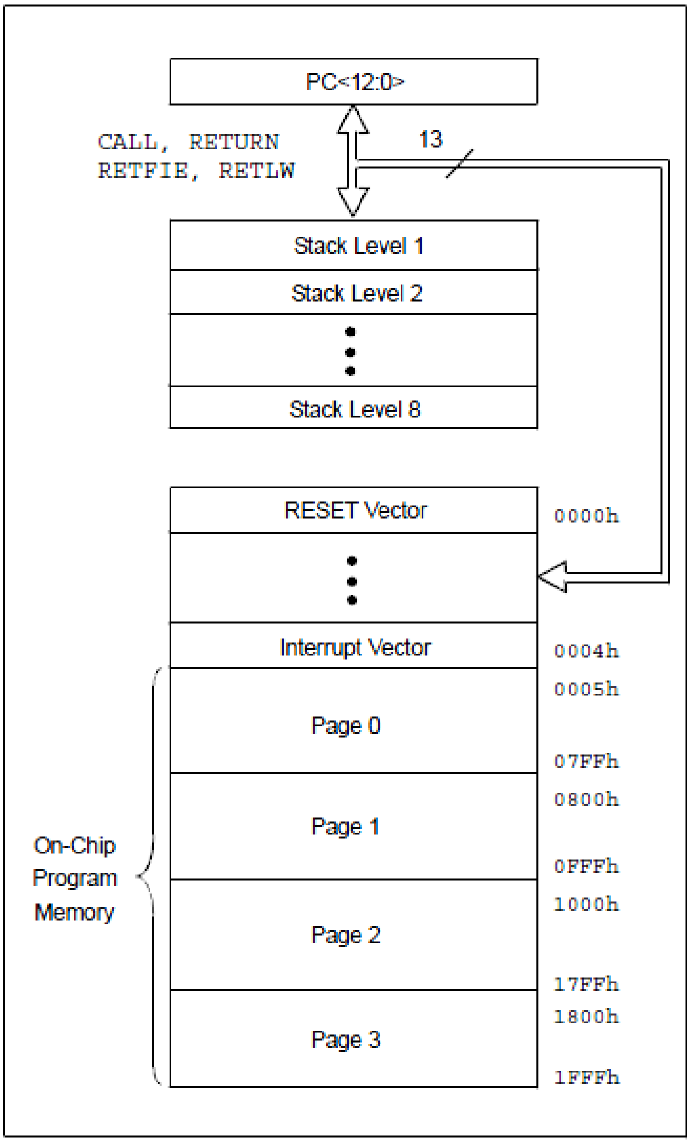


Figure 2.5: PIC 16F877 Memory Maps

The data memory is partitioned into multiple banks which contain the General Purpose Registers and the Special Function Registers (Figure 2.6). Bits RP1 (STATUS<6>) and RP0 (STATUS<5>) are the bank select bits. Each bank extends up to 7Fh (128 bytes). The lower locations of each bank are reserved for the Special Function Registers. Above the Special Function Registers are General Purpose Registers, implemented as static RAM. All implemented banks contain Special Function Registers. Some frequently used Special Function Registers from one bank may be mirrored in another bank for code reduction and quicker access. The register file can be accessed either directly or indirectly through the File Select Register (FSR).

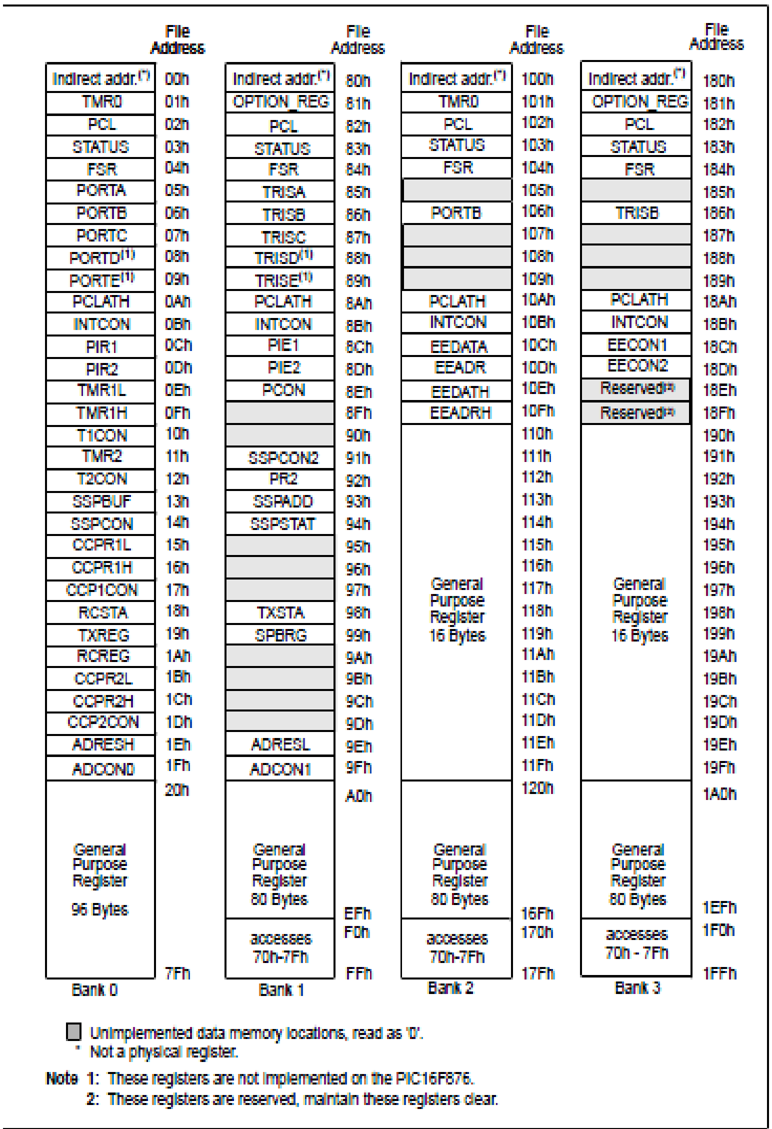


Figure 2.6: PIC 16F877 Register File Map

CHAPTER 3

METHODOLOGY

3.1 BLOCK DIGARAM

3.1.1 BLOCK DIAGRAM OF BODY DETECTOR

Figure 3.1 shows the block diagram of body detector system for this project. At the heart of the Body Detector is a versatile mixer which will detect frequency variations within a small fraction of one percent. While the mixer is deceptively simple, it has a high degree of accuracy as well as flexibility. It starts with sensor detection by the capacitance around human body, thus activate the body detector. This version of body detector only used two detection sections and also requires no special optimization for the sensor and may be easily adjusted to almost any sensor of one's choosing. The block diagram is based on astable oscillator (IC1a) and a non-retrigerable monostable (IC1b) that operates in tendem. Nearly all of the components surrounding IC1 have the same temperature coefficients. Both astable oscillator and the non-retrigerable monostable are housed in the same package (IC1), which means that any warming or cooling of the devices affects both sub-circuits more or less equally. Thus, environmental variations are largely cancelled out.

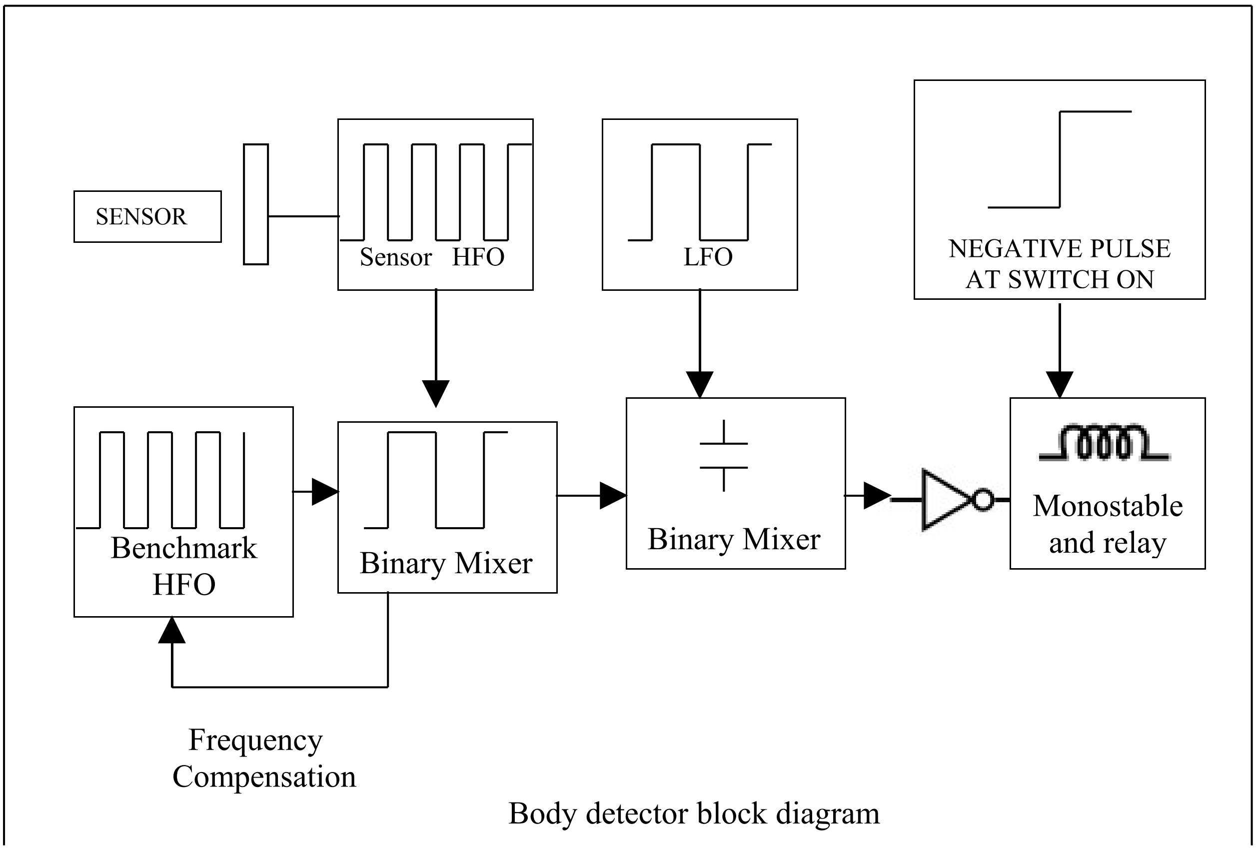


Figure 3.1: Block Diagram of the Body Detector System

3.1.1.1 Sensor

At the block diagram of the system, sensor will be the input to the main system. The sensor which put at the body detector will detect any existence of capacitance human body around the body detector in certain distance. Any metal sensor will do and the sensitivity will be different to each metals. When we set the sensor to be a sheet of tin foil (light sensor), the sensitivity to trigger the body detection is high.

3.1.1.2 Body Detector Circuit

After received the signals form sensor that capacitance is detected, it will trigger the binary mixer and monostable timer. If then a body comes near, the frequency of CMOS dual timer will drop, and therefore monostable timer will go "high" for duration fractionally shorter than the period of astable. The output of CMOS dual timer is fed to the trigger input of another CMOS dual timer. Therefore astable triggers monostable CMOS dual timer.

3.1.2 BLOCK DIAGRAM OF PIC 16F877 MICROCONTROLLER

All the system in this project is controlled by PIC 16F877. This project is using two module of microcontroller board, one for the receiving part of the input from body detector and the other one for transmitting output and displaying part. There are five main parts remaining in microcontroller. There are power circuit, reset circuit, clock circuit and programmer module.

3.1.2.1 **PIC 17F877 PIN ASSIGNMENT**

In Alarm System Using Body Detector, the pin used in PIC 16F877 (Figure 3.2) are mainly at PORTB which include pb0, pb1, pb2, and pb3. While for the voltage supply I used pin11 and pin32 and for ground I used pin12 and pin31. For clock input, I used OSCI1 and OSC2 (pin13 and pin14).

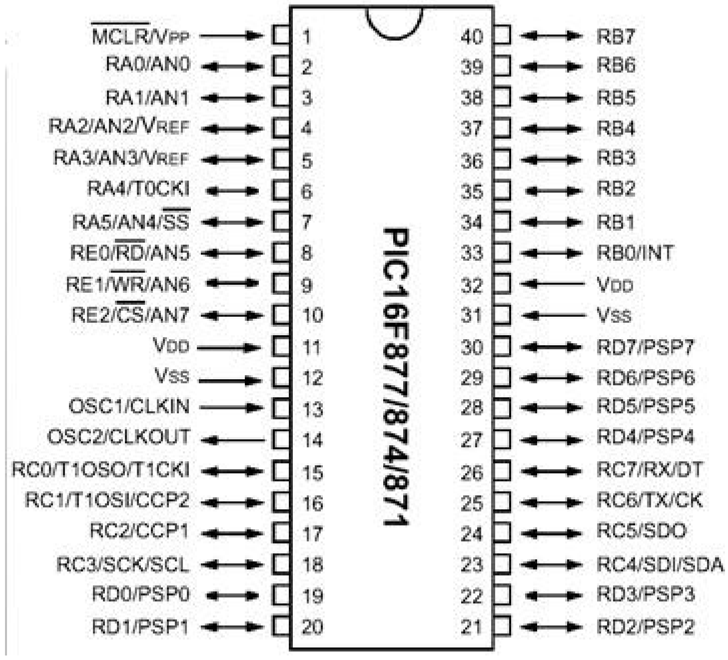


Figure 3.2: Pin Assignment PIC 16F877

3.1.2.2 PIC 16F877 Block Diagram

In PIC 16F877, there are two types of features which are the core features and the peripheral features. The **core features** of PIC 16F877 can be seen at Figure 3.3 (upper part). For core features of PIC16F877, it includes only 35 single word instructions to learn, could operate speed at DC - 20 MHz clock input DC - 200 ns instruction cycle. It also has up to 8K x 14 words of FLASH Program Memory, 368 x 8 bytes of Data Memory (RAM) and 256 x 8 bytes of EEPROM Data Memory and the interrupt capability (up to 14 sources). Same with other processors, PIC16F877 also have direct, indirect and relative addressing modes. Programmable code protection and Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation is available on this microcontroller. It is able to select the oscillator options and have low power, high speed CMOS FLASH/EEPROM technology. With wide operating voltage range: 2.0V to 5.5V the processor could read/write access to program memory. While for the **peripheral features** of PIC 16F877 can be seen at

Figure 3.3 (lower part). This includes the timer which is 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 and Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler. It also have two Capture (16-bit, max. resolution is 12.5 ns) , Compare (16-bit, max. resolution is 200 ns), and PWM modules (max. resolution is 10-bit). Lastly, it includes 10-bit multi-channel Analog-to-Digital converter.

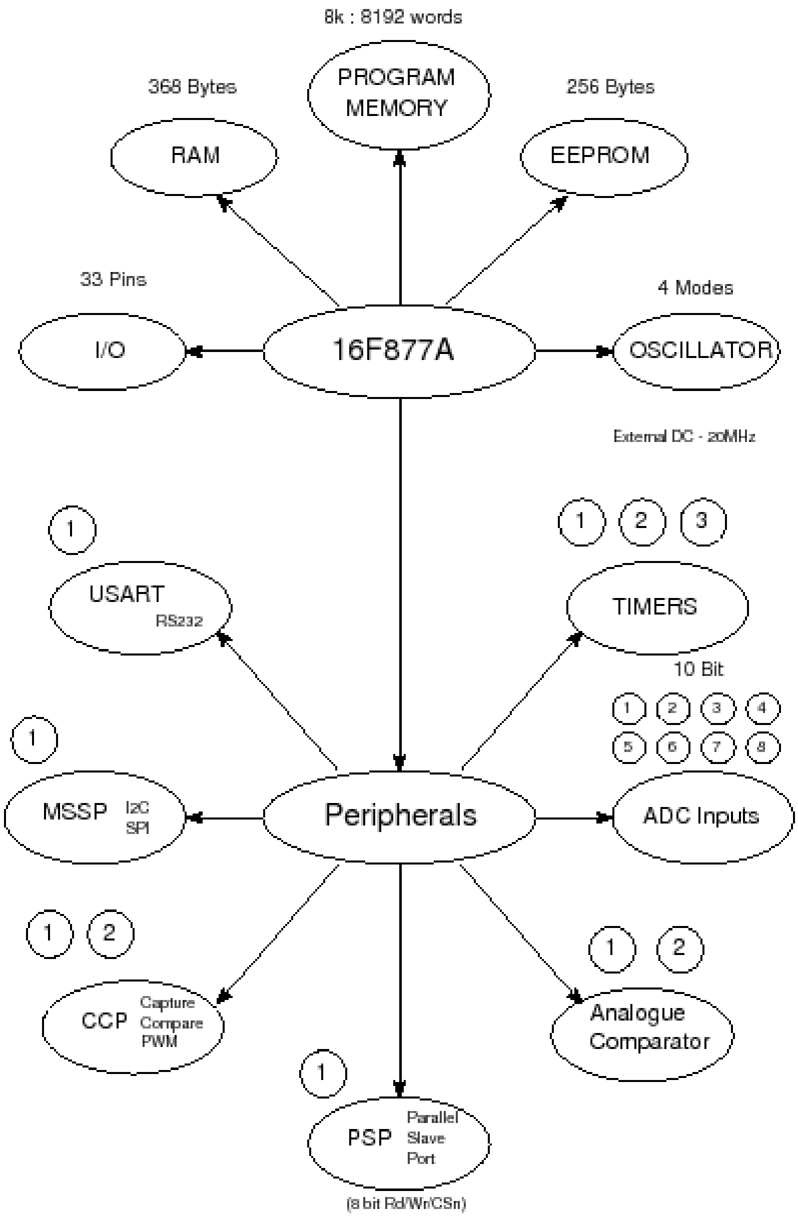


Figure 3.3: PIC 16F877 Block Diagram

3.1.2.3 PIC 16F877 ELECTRONIC DESIGN

For this system, PIC 16F877 will act as the controller for the alarm system application. The output from Body Detector (relay activation) will give input to the microcontroller then it will control the output to the alarm system application especially at the indicators such as buzzer which is the part that will make the alarm ringing. When the input is given, the microcontroller will act as what it has been programmed for. Using the microcontroller it will control the speed and direction of the indicator as desired. The connection of the Operation Mode Connection of PIC 16F877 Line system is shown at Figure 3.4

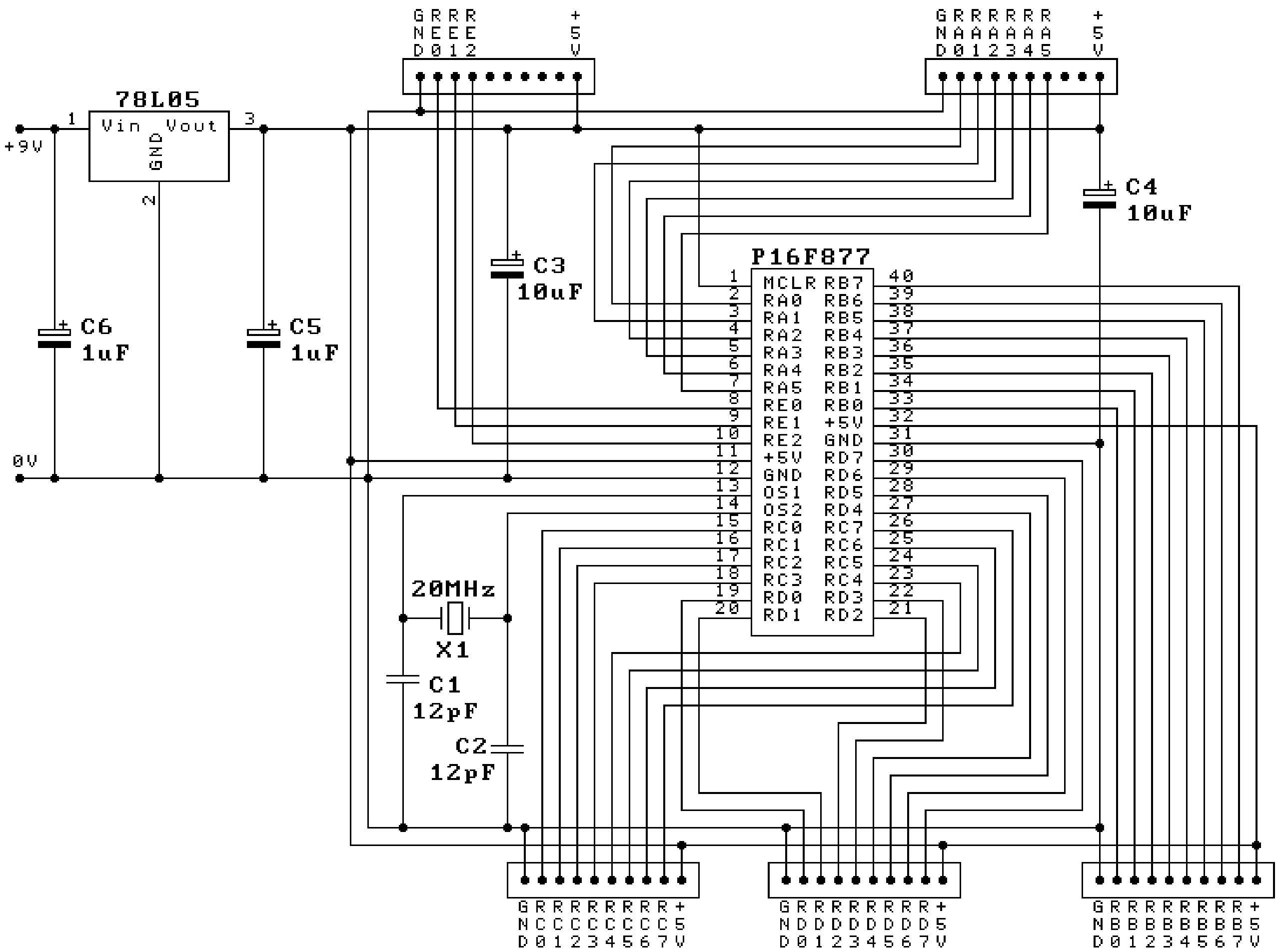


Figure 3.4: Operation Mode Connection of PIC 16F877

3.1.3 BLOCK DIAGRAM OF ALARM SYSTEM

Figure 3.5 shows the block diagram of the system for this project. It starts with sensor detection by the capacitance around human body, thus activate the body detector. Two binary mixers are each based on half of a CMOS dual binary counter. These mix a signal form high frequency oscillator (HFO) with a benchmark frequency. Both oscillators are based on dual timer integrated circuit and both are tuned to the same frequency around 100kHz. The output (relay activation) from the body detector will be integrated with microcontroller type. Thus, the designed programming code in the microcontroller will create an application of alarm system. The system then gets the feedback from the sensors that give the feedback to the body detector so that the body detector will response and user can take action to control the alarm system. For the application, alarm system will received the signals to be activated by the microcontroller programming. To on the alarm system, a short delay is provided at switch-on through capacitor and resistor, so that the user has time to step out of range before monostable timer and the relay are activated.

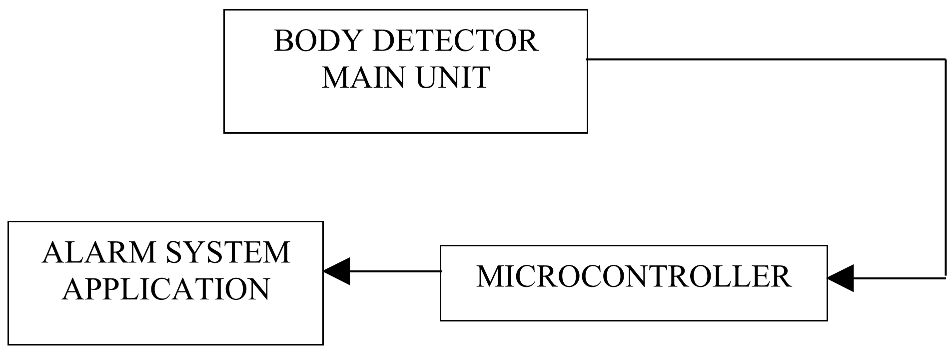
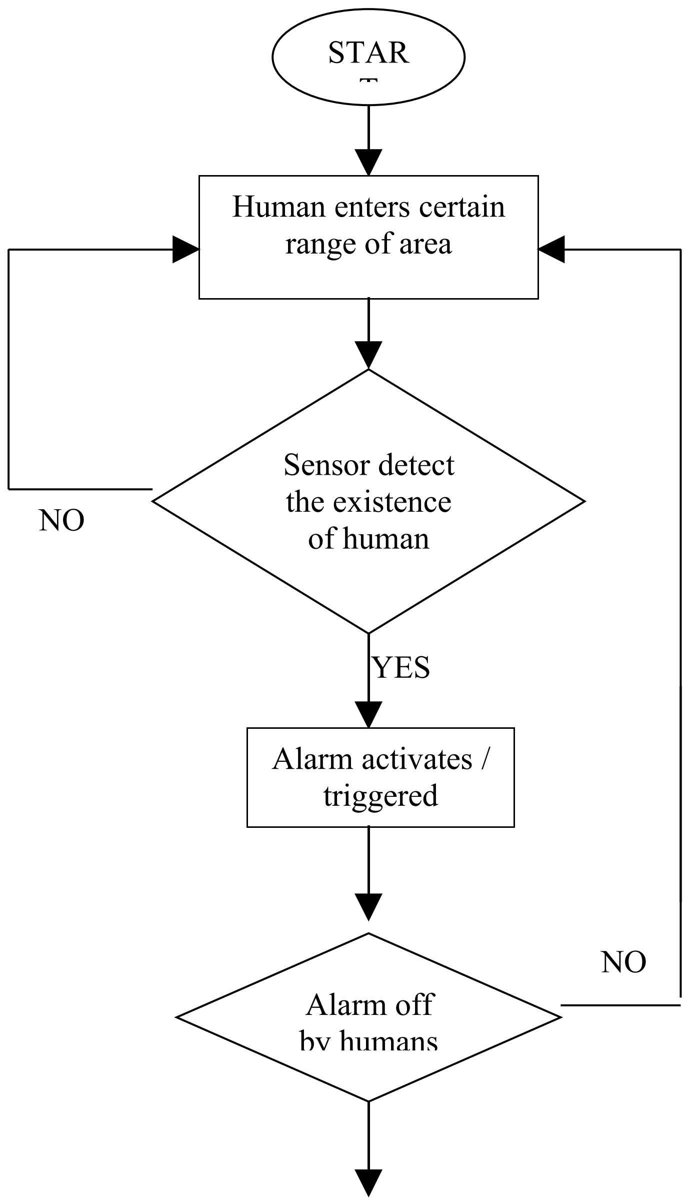


Figure 3.5: Block Diagram of the system

3.2 FLOW CHART

3.2.1 Flowchart of the system

The application of Alarm System Using Body Detector is simple. Once a human body approach the positive plate of capacitor, the main body detector will activate its device if only the human body is in range that the body detector located can detect the reliable shifting in frequency. Then if the Body Detector sensed the human body approaches, it transmits pulses through microcontroller and thus activates the flow of alarm system (buzzer sound). This process requires the users to manually off the power supply himself after once the alarm is activated. The flowchart of the system is shown at Figure 3.6**.**



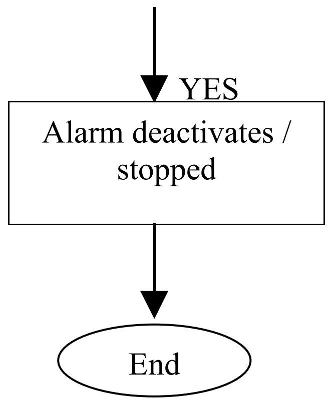
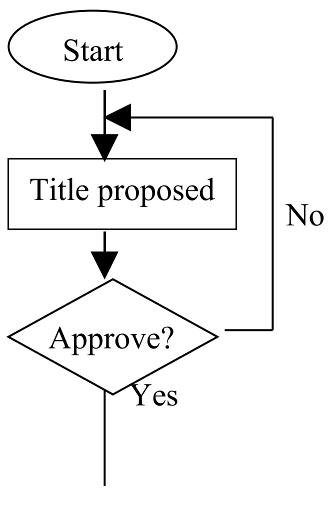


Figure 3.6: Flowchart of the system

3.2.2 Flowchart of methodology

Figure 3.7 shows the flowchart of project methodology. This project will start with proposed the title and fulfill the requirement needed. If the title is accepted then continue to the next level, if not check and correct the mistake then proposed back the title. The next level after the title has been proposed is doing the research on the problem occurred in the previous application and identify the part that need to be improved. After doing the research, the improvement process is divided into two parts which is software and hardware design. After the improvement is done, the both part software and hardware is integrated then test them whether the prototype is function or not. If yes the project is success and if not, test the prototype back.



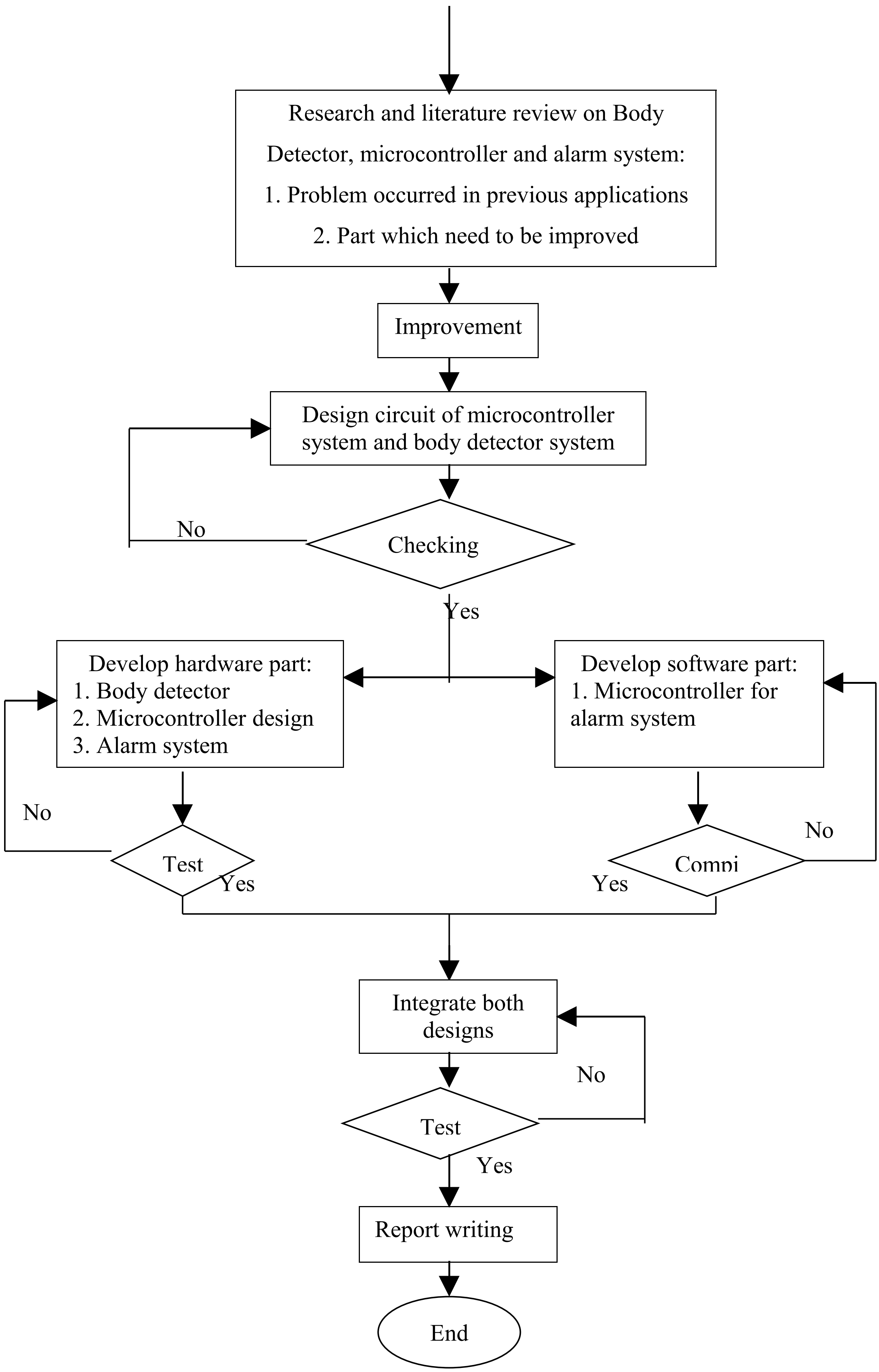

Research and literature review on Body Detector, microcontroller and alarm system:
1. Problem occurred in previous applications
2. Part which need to be improved
Improvement
Design circuit of microcontroller system and body detector system
No
Checking
Yes
Develop hardware part:
1. Body detector
2. Microcontroller design
3. Alarm system
Develop software part:
1. Microcontroller for alarm system
No
Test
Yes
No
Compi
Yes
Integrate both designs
No
Test
Yes
Report writing
End

Figure 3.7: Flowchart methodology of flow project

3.2.3 Flowchart of programming software design

Figure 3.8 shows the flowchart of the programming software design. This software is beginning with the activation of relay. If the relay is activated, the thruster is on and moves according to the direction as it program for. If absence of human body in certain distance, indicator, LED 1 is on. If the system detects the presence of human body, indicator LED 2 and buzzer are on and turn off the thrusters, then starts from the beginning. If the relay is not activates, the alarm system will do nothing.

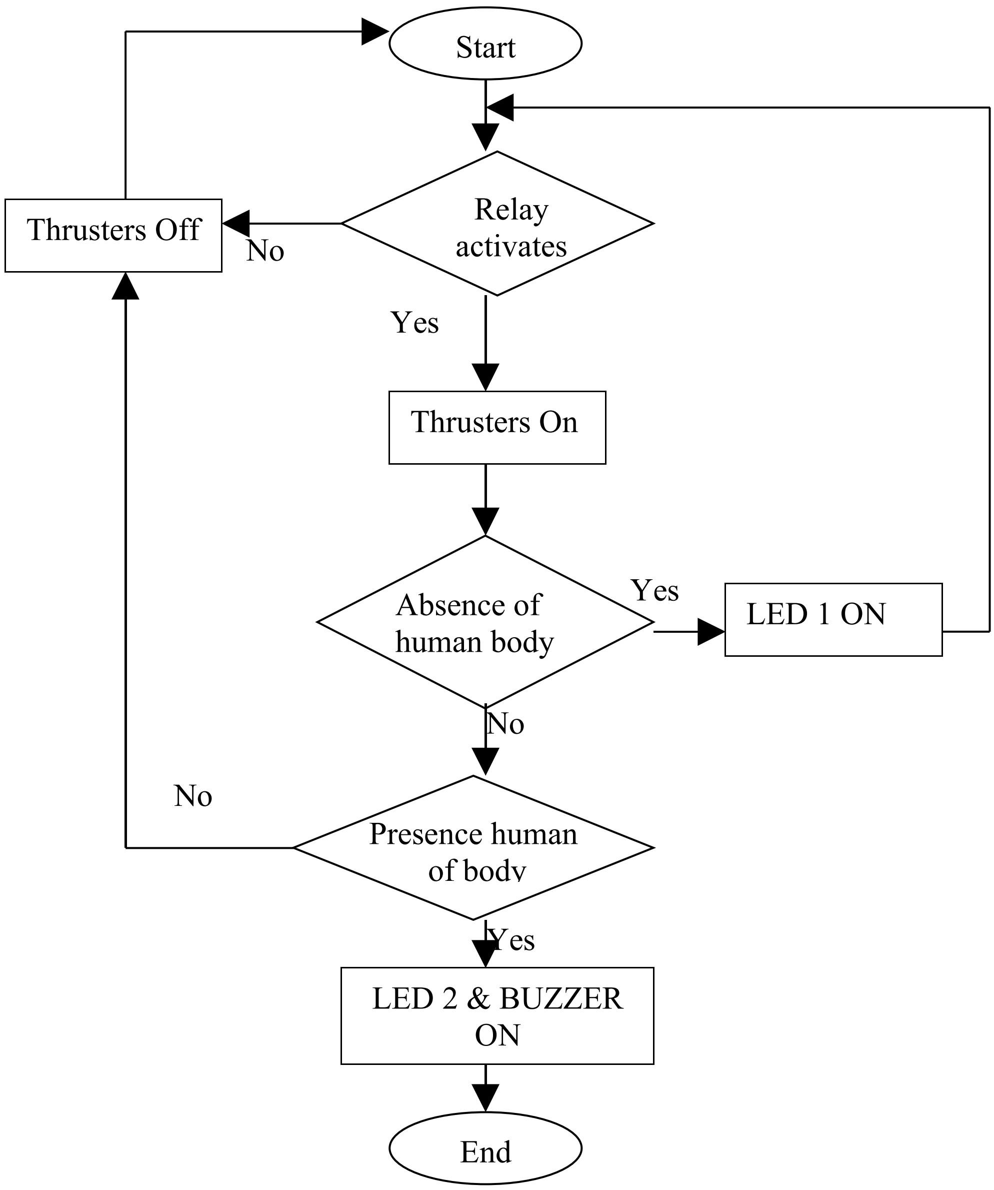


Figure 3.8: Flowchart of programming software design.

CHAPTER 4

HARDWARE DESIGN

4.1 AN OVERVIEW

4.1.1 DESIGN PRINCIPLES

In Alarm System Using Body Detector, it involved several design principles that affect the performance of the output.

4.1.1.1 SENSITIVITY

Bear in mind that body capacitance varies from body to body. All in all, it is sensible to calibrate the Body Detector so that it is sensitive enough to safely trigger, yet not so that it comes too close to its trigger threshold. With using lighter sensor, this can be achieved finely. It is hard to quantify the circuit's sensitivity and stability since this depends on the no of factors, particularly the range it is adjusted to, and the surface area of the sensor. From the prototype of several sensor used, it is showed just over 1.5% shift in sensitivity per 1°C temperature variations. This means that in most situations the circuit is solid at 10cm range, which is more adequate for protecting simple applications such as valuables on a shelf. However, at 20cm range and using the same sensor, temperature becomes significantly problem.

4.1.1.2 STABILITY

Stability is the challenge for the sensitivity. This is essentially because this quantify that the circuit measures; in this case is body capacitance which is so extremely small that minute variations within the circuits itself to swamp the quantity being measured. The importance of achieving a high order of stability still remains a significant problem at the end of the day and the final circuit exhibits a high degree of stability. It is recommended in the future, that this project will use PCB (printed circuit board) in order to achieve higher stability.

4.1.1.3 **OPTIMIZATION**

The Body Detector is functioned well under a wide variety of conditions without further modification. Ideally, it should be optimized for use with a specific metal sensor. The need of for such modifications arises because the attachment of a sensor plate towards the capacitor C1 will increases the value of sensor h.f.o (high frequency oscillation). IC1a is timing the capacitor C1. this means that multi turn presets VR2 needs to be turned back, which exposes a benchmark oscillator IC2a to a little more frequency drift than IC1a. the solution in the circuit is by simply selected the metallised ceramic plate of 4p7 F which has a zero temperature coefficients. Therefore, by increasing the value of benchmark- h.f.o's timing capacitor C4 (by adding CX in parallel with C4) which is C2 with the same value. Such final optimization is being done on the final application of Alarm System Using Body Detector.

4.2 ELECTRONIC DESIGN OF BODY DETECTOR

4.2.1 GENERAL CONSTRUCTION

The Body Detector is built up on a small independent board measuring about 25cm x 10cm. The topside component design is shown in Figure 4.1. All the components should fit into place without too much difficulty. However, a fine-tipped soldering iron would help since this is a compact circuit board.

Before soldering and commencing construction work, adjust preset VR1 to about 50kΩ, VR2 to 5kΩ, VR3 to 10kΩ, VR4 to 250kΩ, and VR5 to 10kΩ. Special note is taking with the orientation of electrolytic capacitors C9, C11 and C13. The electrolytic capacitors must also suitable rated which is about 16V or higher. Any lead which is taken from the board to a sensor (sheet of tin foil) should be soldered to the solder pin and the free ad bolted to the sensor to ensure god electrical contact.

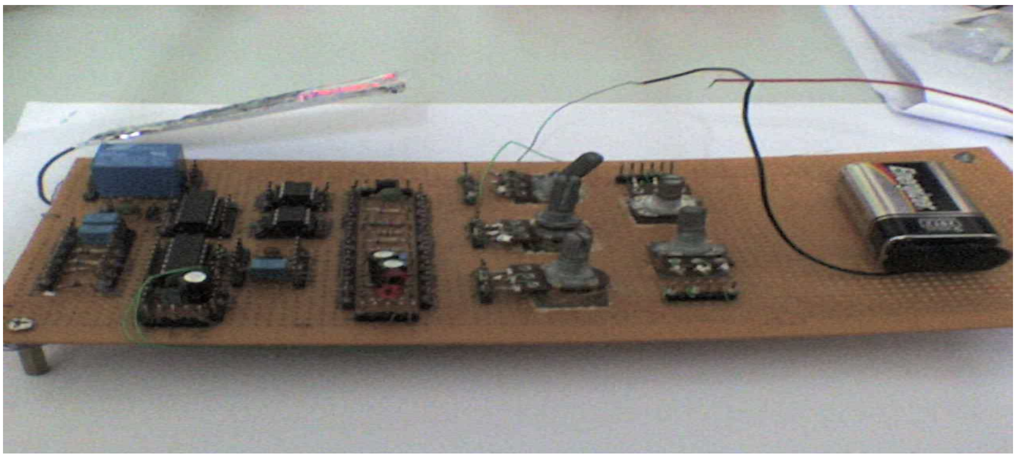


Figure 4.1: Body detector board (off state)

4.2.2 CIRCUIT DETAIL

4.2.2.1 Circuit Components

For Alarm System Using Body Detector, basic components are used such as resistor and capacitor as main components. Other than that, components such as potentiometer, diode, transistor, timer, relay and LED are used. Detail of circuit components is shown at Table 4.1.

Table 4.1: The Body Detector Circuit Components

No.	ITEMS	PRESCRIPTION	SYMBOL
1.	Resistor	1kΩ (3 off)	R1, R6, R8
2.	Resistor	68kΩ (3 off)	R2, R4, R7
3.	Resistor	100kΩ	R3
4.	Resistor	2M2Ω	R5
5.	Resistor	5k6Ω	R9
6.	Potentiometer	100k 25-turn cermet preset,top adjust	VR1
7.	Potentiometer	10k 25-turn cermet preset, top adjust	VR2
8.	Potentiometer	500k 25-turn cermet preset, top adjust (3 off)	VR3, VR4, VR5
9.	Capacitor	4p7F ceramic (2 off)	C1, C3
10.	Capacitor	10 nF polyester (3 off)	C2, C4, C10
11.	Capacitor	100 nF polyester (5 off)	C5, C6, C7, C8. C12
11.	Capacitor	100µF radial elect 16V (3 off)	C9, C11, C13
12.	Diode	1N4148 signal diode (3 off)	D1, D2, D3
13.	Led	3mm ultrabright l.e.d, red	D4

14.	Transistor	2N3819 field effect transistor (f.e.t)	TR1
15.	Transistor	BC549 small signal transistor	TR2
16.	CMOS	7556 CMOS dual timer (2 off)	IC1
17.	Transistor	TL071CN j.f.e.t. op. amp	IC2
18.	CMOS	7555 CMOS dual timer	IC3
19.	Relay	12V d.c coil, Telecom TX series, relay with 2A 30V d.c d.p.c.o contact	RLA
20.	Independent Board		
21.	Stand-off pillars	(4 off)	
22.	Battery clip	(2 off)	
23.	Tin foil		
24.	Battery	9V alkaline battery	

4.2.2.2 Circuit Explanation

The full circuit diagram for Body Detector is shown at Figure 4.2. The functions of IC1a 7556 CMOS dual timer (astable oscillator) and IC1b 7556 CMOS dual timer (non-retrigerable monostable) operating in tendem. Notice that both astable oscillator and non-retrigerable monostable are housed in the same package of IC1, which means that any warming or cooling of the device affects both sub-circuits more or less equally.

The **frequency of oscillator** IC1a is calculated by the formula;

f IC1a = 1.46 / [(VR1 + VR2) X C1] Hz

While the **period time** of monostable IC1b is calculated by formula;

t IC1b = 0.69 X (VR3 + R1) X C3 second

IC1a is oscillates at around 100 kHz, although its frequency is dependent to a large degree of mass of the sensor. A very small value timing capacitor 4p7F (C1) is employed for IC1a, so that the oscillator will readily respond to the body's electrical field. Capacitor 4p7F C3 used at IC1b is the same value as C1. Both C1 and C3 should have a zero temperature coefficient because the coupling C2 and C4 (each 10 nF) has been included in IC1a and IC1b for greater stability along with supplying decoupling capacitors C12 and C13 (each 10 nF and 100 uF).

All the timing components of IC1a and IC1b have identical temperature coefficients. This is why variable resistor (potentiometers) are used. Resistor R1 (1kΩ) only have small effect on stability of the circuit. In this case, VR1 should never be reduced than 50k otherwise the IC1 is sure to be self-destruct. The output of the non-retrigerable monostable timer IC1b is fed to a standard diode. Charging is both limited and controller by resistor R2 (68kΩ) and R3 (100kΩ), so that the charge on capacitor C6 (100 nF) will vary between 5.5V and 6.5V as a body comes near the sensor. The values of resistors R2, R3 and capacitor C6 are chosen to be large enough to damp mains transients and electromagnetic pulse for greater reliability. This may be perfect enough by tapping the sensor rapidly. If it is tapped rapidly enough the Body Detector will fail to trigger. The value of capacitor C6 will increase if there is problem in his detection area. A simple inverting comparator is formed around IC2 TL071CN j.f.e.t op. amp. and associated components. The threshold voltage is set by preset VR4 so that the output at IC2 pin 1 swings 'high' or 'low' as the inverting input across the threshold. It will swing 'low' as a body approaches the sensor (assuming that VR4 is suitable adjusted- since VR4 is for the LED illuminating).

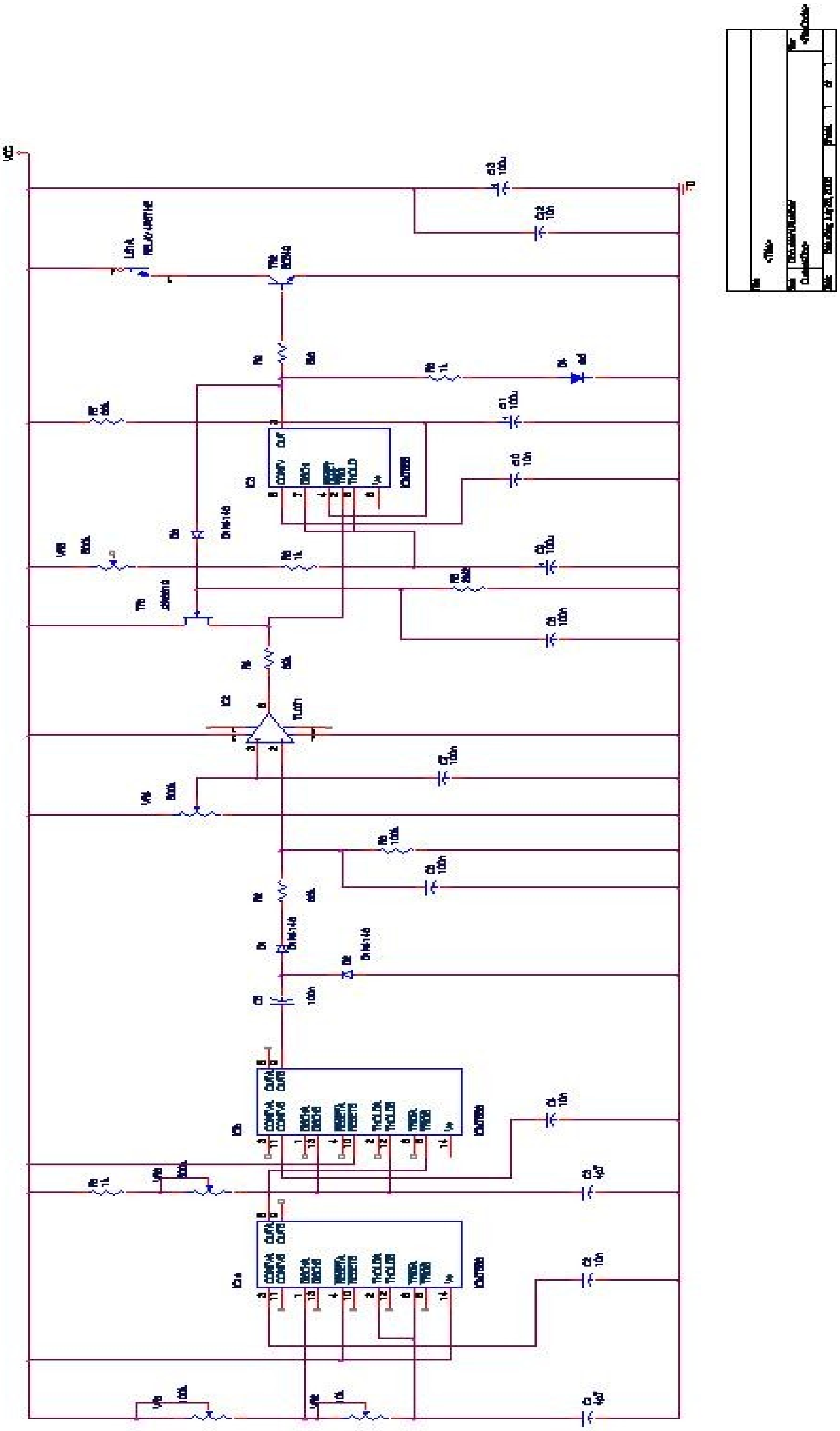


Figure 4.2: Body Detector Circuit Diagram

4.2.2.3 Power Source

In Body Detector circuitry, there is included no reverse polarity protection so that it may be run off both 9V and 12V (up to three days and nights of a small 9V alkaline battery). Therefore, special care needs to be taken that the power is connected the correct way round. The circuit is unusually stable; therefore no voltage regulation is included (if compared to PIC 16F877 board). However, a clean regulated voltage supply is sure to improve the performance of body detector.

The circuit is virtually immune to static and to e.m.f- induced eddy currents in the body. The Body Detector is designed to detect the electrical field surrounding the human body and has high degree of immunity to a.c. fields as well as being able to function well out of range of such fields.

4.2.2.4 Blanking Out

Blanking out represents the ‘blanking circuit’ that blanks the activation of the Relay (RLA) after it has been activated. The resistor R4 together with the TR1, R5, C8 and D3 represent the blanking circuit which for a brief moment blanks the action of relay. This ensures that the relay’s emf does not destabilize the balanced circuit. The effect of these components may be showed by holding the one’s hand to the sensor continually. As IC3’s timing perios comes to an end, and LED D4 extinguishes a fraction of a second delay is noticed before it illuminating again.

A monostable timer IC3, triggers the relay for a period determined by preset VR5 and resistor R8. Its period time will be seconds so that it can be adjusted between 1s to 30s. If different timing periods are required, the value of capacitor C9 may be increased for longer time periods and vice versa. The output pf monostable timer 1C3 (pin 3) provides current for transistor TR2 , which in turn switches relay RLA. The arrangement at IC3 reset pin 4 delays the circuit’s coming alive at switch-on by about 7 seconds so that one has stand back from the circuit after switching it on. Failing this, body capacitance could trigger the circuit at any time the switch is on.

Although in circuit diagram Figure 4.2, there is no direct provision for a delay before the circuit is triggered. But, there can be arranged by wiring a large value of capacitor in parallel with C6, then reducing preset VR4 as far as possible (clockwise) without disabling IC2's output.

4.2.2.5 Relay

One set of relay contacts is routed to three solder pins TR1, VR5 and R7 and these may be used to wire up an external load. Since the relay is rated 60W (2A 30Vd.c), a maximum powerful siren may be wired to the contacts. The Body Detector may also be wired to the input of standard alarm system (Figure 4.3).

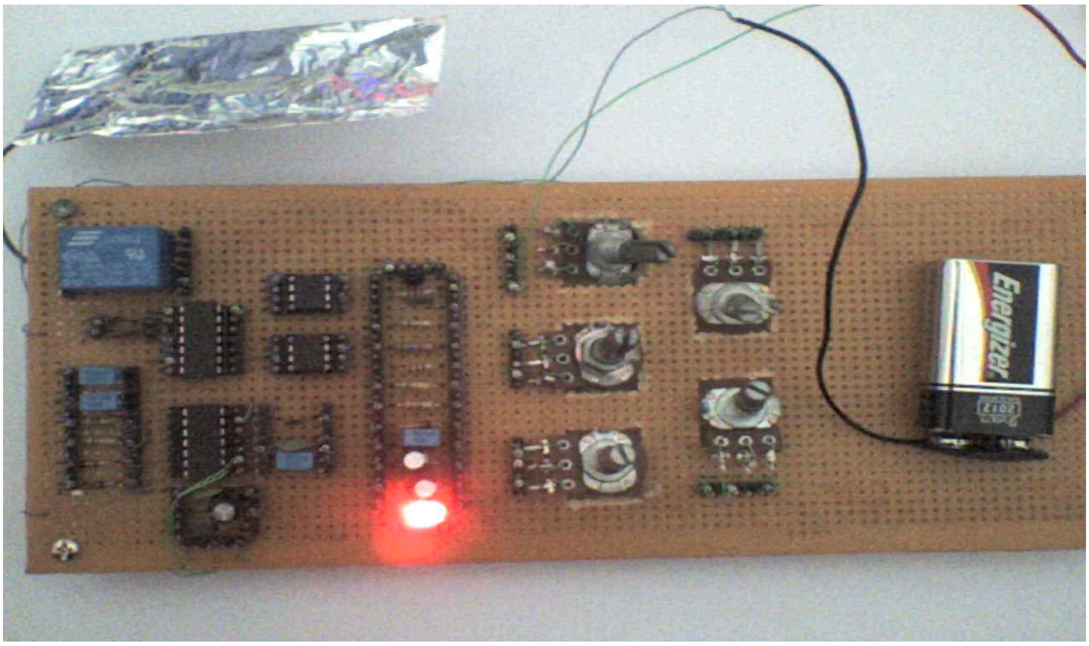


Figure 4.3: Body detector board (on state)

4.3 ELECTRONIC DESIGN OF PIC 16F877

4.3.1 An Overview of PIC Microcontroller Board Design

PIC Microcontroller is one of the versatile microcontroller families in the market and become an inexpensive single-chip computer. Single-chip computer means that the entire computer system lies within the confines of the integrated circuit chip The PICmicro^{R} Microcontroller was first introduced in the early of 1980 by General Instruments for their product design and known as "Programmable Interface Controller". One of the main advantages dealing with PIC Microcontroller is the large database of information and technical support from the internet. Besides lots of books that may help new users learn more about the PIC Microcontroller, there are also a PICmicro Microcontroller specific user group that offers free tutorials and advice on PIC projects.

The PIC family is a small microcontroller designed for fast input/output control using a small instruction set. The PIC is a low-cost microcontroller and can be reprogrammed thousands of times again and again using Flash programmable EEPROM using just electronic signals from a PC like a higher-level microcontroller such as BASIC stamps. The PIC Microcontroller is able to store and run unique programs and can be programmed to perform functions based on predetermined situations (1/O-line logic) and selections. Based on PIC Microcontroller versatility, their features add a lot of power, control, and options at little cost in this project construction.

There are a lot of considerations in choosing the right microcontroller in this project. Different factors such as the physical size, the number and type of inputs and outputs, the speed, the forms of external communication, the random access memory (RAM), read-only memory (ROM), arithmetic logic unit (ALU), central processing unit (CPU), analog-to-digital converters (ADC), digital-to-analog converter (DAC), timers, serial ports, parallel ports, the availability and the price itself.

4.3.2 PIC16F877 Microcontroller Unit (MCU)

PIC microcontrollers are fast, cheap and low power machines that can handle just about any control or data processing application imaginable. PIC 16F877A is a self contained computer-on-a-chip and supported by CMOS Technology and have several advantages:-

a) It has low-power, high-speed Flash/EEPROM Technology and works well with thousands of electronic products.
b) It has fully static design
c) It does cover wide operating voltage range (2.0V to 5.5V) for most electronic application.
d) Fulfill wide variety of commercial and Industrial temperature ranges
e) Low-power consumption

PIC 16F877A Microcontroller differs from a Microprocessor in many ways. The most important is the chip functionality. In order to use Microprocessor, other components such as memory, or components for receiving and sending data must be added to it while PIC 16F877A microcontroller is designed to be all of that in only one chip. PIC 16F877A microcontroller doesn't need external components for its application because all necessary peripherals are already built into it. In other words, we save the time and space needed to construct devices.

The flash memory in the PIC16F877A microcontroller permits the microcontroller to be programmed, erased and programmed again repeatedly. By using PIC16F877A microcontroller, it does not need a special programmer and n ultraviolet eraser to achieve this special reprogramming capability.

4.3.3 PIC16F877 Circuit Detail

In PIC16F877 circuit diagram, there are several circuits that is compulsory for the system to function well. It were included the power supply, clock circuit, and reset circuit. Power supply circuit (Figure 4.4) is needed in the basic PIC16F877 circuitry because 7805 regulator need to regulate the voltage supply of (>6V to 12V) so that the suitable voltage supply will drop at the PIC16F877 Vdd pin12 and make the PIC to functioned.

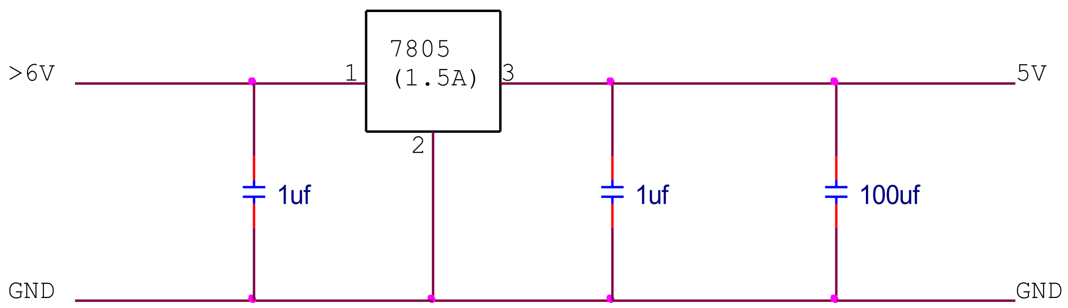


Figure 4.4: PIC 16F877 power supply circuit

A simple RC circuit (Figure 4.5) is used to produce action-synchronizing clock pulses. 8-MHz resonator is used for the operation clock oscillation by PIC. The precision of this oscillation frequency doesn't influence the precision of the clock. The precision of the clock is decided by the precision of the frequency which is inputted to pin13 (OSC1) and pin14 (OSC2). Because it doesn't need the high-speed operation of PIC at the circuit this time, 8MHz is used.

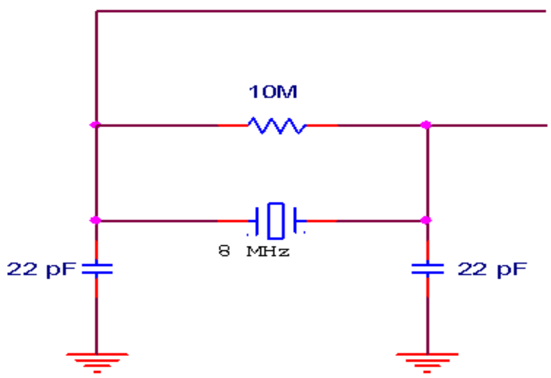


Figure 4.5: PIC 16F877 clock circuit

Meanwhile, the reset circuit (Figure 4.6) is used so that the program from a known state. It will be reset when the Master Clear (/MCLR) pin is connected to the 0V supply (ground). The PIC has internal circuits to perform this function at power on and the simplest design involve merely connecting the /MCLR pin directly to the positive voltage supply through a resistor to the positive voltage supply. When the power supply is connected, the voltage rise too slowly then this reset function may not work. By having a capacitor, at switch on, the capacitor will discharges. The PIC will be held reset until the voltage /MCLR is above threshold value.

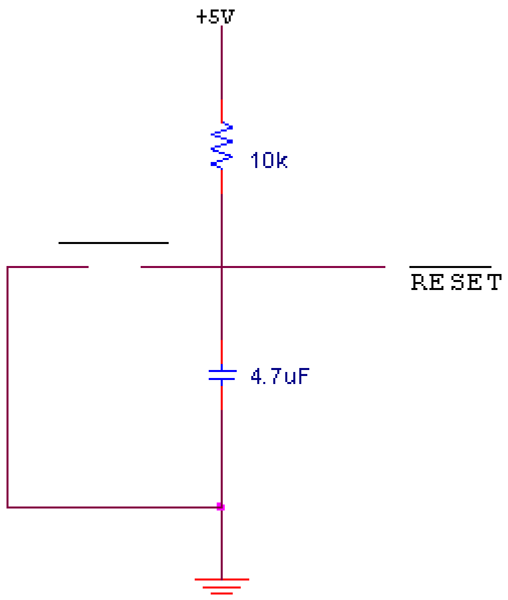


Figure 4.6: PIC 16F877 reset circuit

The PIC Controller board in this project used a 40-PIN PIC 16F877 as main controller. In this design (Figure 4.7) , port B is used as a bidirectional port which is as an input and output port. Port B pin0, pin1, pin 2 and pin 3 are used to control input and output that work as an indicator of the working system. In initial condition, Port B pin 0, pin 1 and pin 3 will be set as logic low. This condition will remain the pins as output mode while Port B pin2 will be set as logic high and will remain the pin as input digital (pulse). Output pulse from Body Detector will be the input digital for PIC pin2. When input pulse is detected the change of high and low frequency, red LED controlled by PIC pin0 will turns on and buzzer controlled by PIC pin1 and pin3 will on. The green LED will indicate the system when PIC is not functioned for several seconds (delay). And for the voltage supply for this PIC board, 9V alkaline battery is used since this project will be stressed on the ability of this device to be portable.

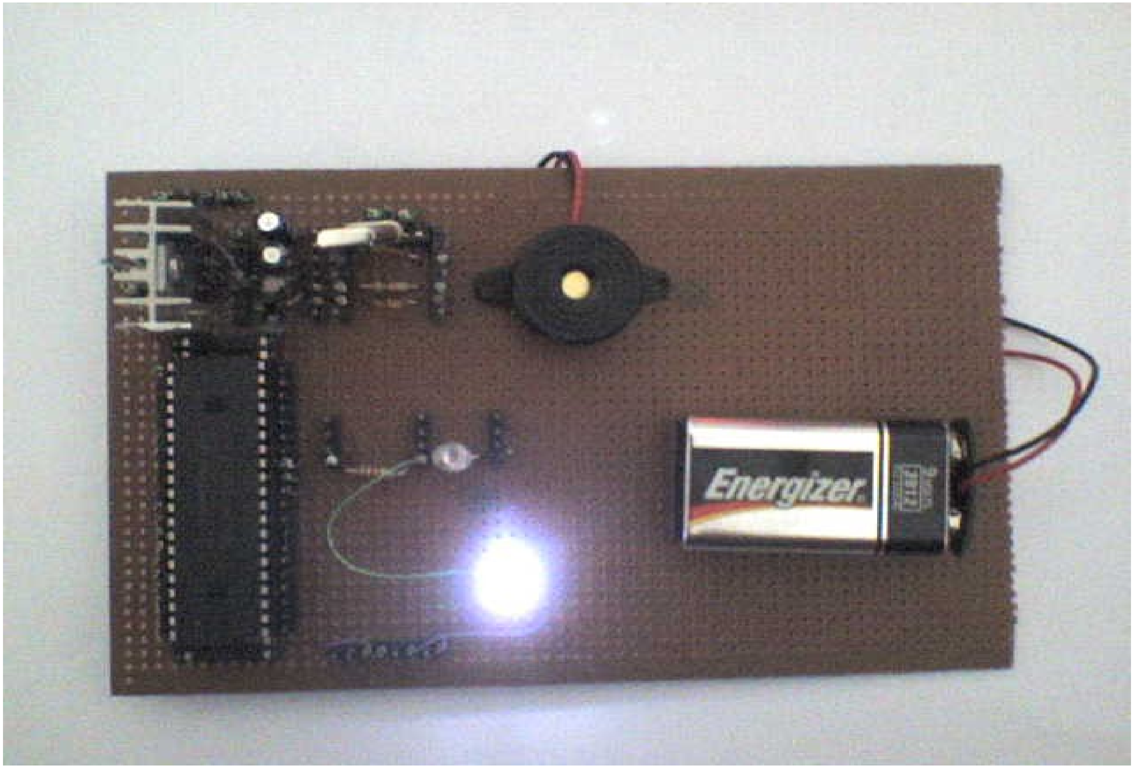


Figure 4.7: PIC16F877 Board Circuitry

4.3.4 Circuit Components

In developing the microcontroller board PIC16F877, the very important components is PIC 16F877 as the brain system and voltage regulator. Other components such as crystal, resistor and capacitance are also used. While for the applications, buzzer and LED are used. Detail of circuit components is shown at Table 4.2.

Table 4.2: The PIC16F877 circuit components

NO.	ITEMS	PRESCRIPTION	SYMBOL
1.	PIC microcontroller	PIC16F877	PIC
2.	Voltage Regulator	7805 voltage regulator	78L05
3.	Crystal	Crystal 8Mhz	X1
4.	Resistor	Resistor 10kΩ (3 off)	R1, R2, R3
5.	Capacitor	Capacitor 12pF (2 off)	C1, C2
6.	Capacitor	Capacitor 10µF (2 off)	C3, C4
7.	Capacitor	Capacitor 1µF (2 off)	C5, C6
8.	LED	3mm ultrabright l.e.d, red	D1
9.	LED	3mm ultrabright l.e.d, red	D2
10.	Buzzer	Buzzer 5V-12V	B1
11.	Independent Board		
12.	Battery	9V alkaline battery	
13.	Stand off pillars	(4 off)	
14.	Battery Clip	(2 off)	

4.3.5 Communication Devices: UIC00A USB ICSP PIC Programmer

In this project, data and information flow from Body Detector circuitry IC1b pin9 to PIC16F877 Microcontroller PortB pin3 system through UIC00A USB ICSP PIC Programmer (Figure 4.8). Assess connectivity plays big roles in evaluating the pulse network performance and Body Detector have tended to use serial communication for their connectivity. While deploying serial communication for Body Detector system, UIC00A USB ICSP PIC Programmer provides a well-known and reliable system for short range wired communications such in this project. UIC00A USB ICSP PIC Programmer has low communications speed, ranging from 9600 bits per second (bps) to 115.2 kilo bits per second (Kbps). UIC00A USB ICSP PIC Programmer links use unbalanced lines that refer to electrical characteristics of the signal on the lines. In this communication, the signal voltage is applied to one wire while others are referenced to a common ground.

Since UIC00A USB ICSP PIC Programmer is a point to point communication, it requiring individual cable to be installed each network device and the control system. By using UIC00A USB ICSP PIC Programmer for Alarm System Using Body Detector System communication, several advantages can be gained such as the hardware and programming requirements are simple and inexpensive and it needs only a mini USB cable and a rainbow cable for programming (Figure 4.9).

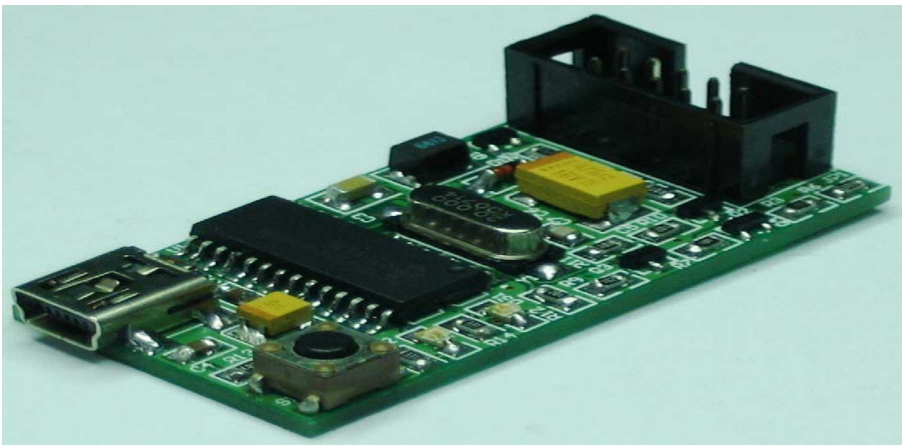


Figure 4.8: for UIC00A USB ICSP PIC Programmer board

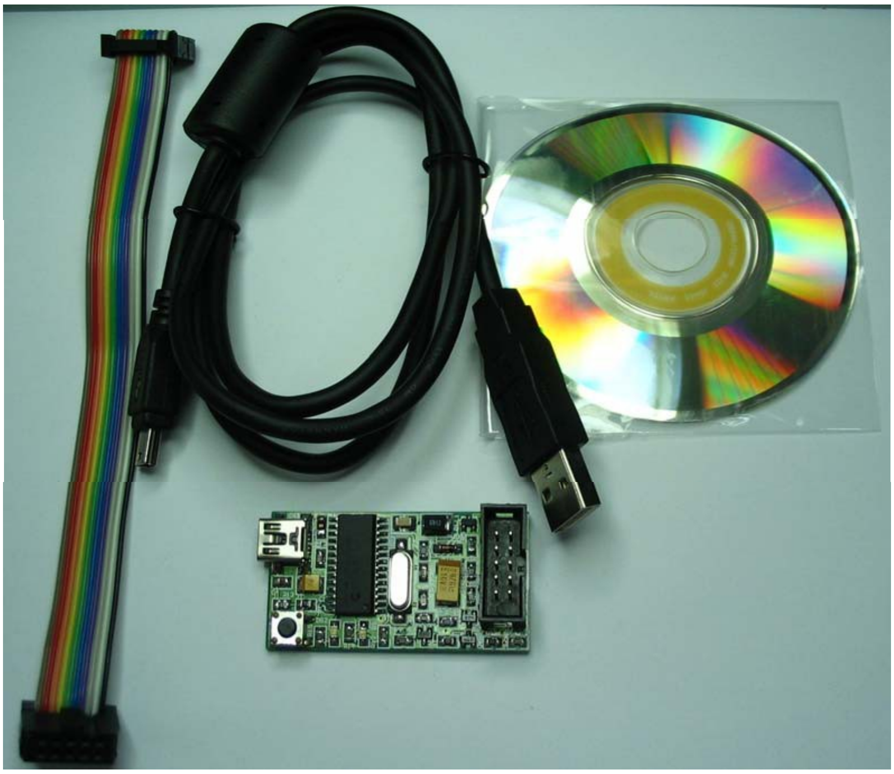


Figure 4.9: UIC00A USB ICSP PIC Programmer board with mini USB cable, programming cable and installer

Figure 4.10 shows the UIC00A USB ICSP PIC Programmer board layout.

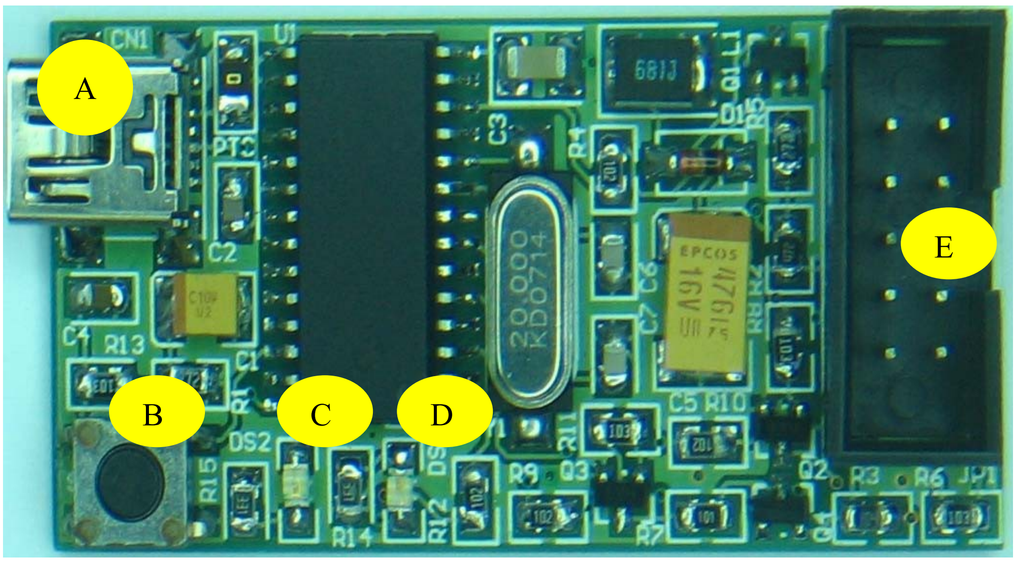


Figure 4.10: UIC00A USB ICSP PIC Programmer board layout

Table 4.3: Function of UIC00A USB ICSP PIC Programmer

LABEL	FUNCTION
A	Mini USB port socket
B	Switch to initiate write device programming
C	Main power supply indicator LED, Yellow
D	Busy indicator LED, Red
E	IDC Box Header for programming connector

A – Is for USB connection to PC desktop or laptop. Must be connected the mini header of USB cable to this socket.

B – Is a switch (push button) which may be used to initiate the write device function when *programmer>Write on PICkit Button* is checked.

C – Is a LED (yellow) to indicate the main power supply of UIC00A. It should be ON once USB connection from UIC00A to computer of Laptop is ready.

D – Is a LED (red) to indicate busy function such as UIC00A is in program mode or is alerting that a function is in progress.

E – Is an IDC box header for programming cable. Must be connected one end of programming cable to this header, while the other end to target board.

CHAPTER 5

SOFTWARE IMPLEMENTATION

5.1 PICBASIC PROGRAMMING

5.1.1 An Overview

PicBasic Pro allows us to use assembly language code mixed together with our BASIC code. The PicBasic Pro Compiler (or PBP) makes it even quicker and easier for you to program Microchip Technology's powerful PICmicro microcontrollers (MCUs). The English-like BASIC language is much easier to read and write than the quirky Microchip assembly language. The PicBasic Pro Compiler is "BASIC Stamp II like" and has most of the libraries and functions of both the BASIC Stamp I and II. Being a true compiler, programs execute much faster and may be longer than their Stamp equivalents. PBP is not quite as compatible with the BASIC Stamps as our original PicBasic Compiler is with the BS1. Decisions were made that we hope improve the language overall. One of these was to add a real IF..THEN..ELSE..ENDIF instead of the IF..THEN(GOTO) of theStamps. These differences are spelled out later in this manual. PBP defaults to create files that run on a PIC16F84-04/P clocked at 4MHz. Only a minimum of other parts are necessary: 2 22pf capacitors for the 4MHz crystal, a 4.7K pull-up resistor tied to the /MCLR pin and a suitable 5- volt power supply. PICmicro MCUs other than the 16F84, as well as oscillators of frequencies other than 4MHz, may be used with the PicBasic Pro Compiler. The PicBasic Pro Compiler files are compressed into the self-extracting file on the included disk. They must be uncompressed before use.

To install and uncompress the software, run (click on) INSTALL.BAT. If the PBP directory already exists, itmay get an error message and the installation will continue. All of the necessary files will be installed to a subdirectory named C:\PBP on the hard drive. The uncompressed READ.ME file has the latest information about the PicBasic Pro Compiler. Make sure that FILES and BUFFERS are set to at least 50 in CONFIG.SYS file. Depending on how many FILES and BUFFERS are already in use by system, allocating an even larger number may be necessary. In general, PicBasic language provides understood language, a widely standardized language and very productive language. Features like bit manipulation, bit field manipulation, direct memory addressing, and the ability to manipulate function addresses pointers have included in PicBasic language. In other words, PicBasic language is the only popular high level language that can be conveniently used for a microcontroller device such as for PIC 16F877 microcontroller to perform specific task in Alarm System Using Body Detector.

In constructing product development, the easiest way is to begin program development is to write down any available idea and specification. By drawing out a number of possible solutions and examine each program pattern in order to find the simplest and most reliable option. At this stage, any early specification about the program like flowchart, block diagram, I/O connection pins plan is being planned properly. The Alarm System Using Body Detector using Port B as an Input and Output at the same time.

5.1.2 PicBasic Command

In Alarm System Using Body Detector, the command that are used is to delay the function of PIC in 7 seconds, to capture the input frequency, to read the data and detect the shift of frequency changing in µs and activate the flows of alarm system applications. Below are several commands that were used to accomplish the project.

5.1.2.1 Define Command

Some elements, like the clock oscillator frequency and the LCD pin locations, are predefined in PicBasic. **DEFINE** allows a PicBasic program to change these definitions, if desired. **DEFINE** may be used to change the predefined oscillator value, the **DEBUG** pins and baud rate and the LCD pin locations, among other things. These definitions must be in all upper case, exactly as shown. If not, the compiler may not recognize them. No error message will be produced for **DEFINE**s the compiler does not recognize. See the appropriate sections of the manual for specific information on these definitions. In this project, **DEFINE** is used to define the oscillator.

DEFINE OSC 8 ‘Oscillator speed in 8MHz

5.1.2.2 Tris Command

TRIS register is used to set a pin or port to an output or input. Setting a TRIS bit to 0 makes its corresponding port pin an output. Setting a TRIS bit to 1 makes its corresponding port pin an input. Below is the TRIS setting for this project.

```
trisb.0 = 0     'set as output for LED
trisb.1 = 0      'set as output for BUZZER
trisb.2 = 1     'set as input digital (PULSE)
trisb.3 = 0     'set as output for BUZZER
```

5.1.2.3 **Sleep Command**

SLEEP *period*

The microcontroller is placed into low power mode for *Period* seconds. *Period* is 16-bits, so delays can be up to 65,535 seconds (just over 18hours). **SLEEP** uses the Watchdog Timer so it is independent of the actual oscillator frequency. The granularity is about 2.3 seconds and may vary based on device specifics and temperature. This variance is unlike the BASIC Stamp. The change was necessitated because when the PICmicro MCU executes a Watchdog Timer reset, it resets many of the internal registers to predefined values. These values may differ greatly from what your program may expect. By running the **SLEEP** command uncalibrated, this issue is sidestepped. In this project, we set 7 seconds blanking out at the time PIC is given the voltage supply so that one's will have time to step out the range of Body Detector located.

SLEEP 7 ‘Sleep for about 7 seconds

5.1.2.4 Count Command

COUNT *Pin, Period, Var*

Count the number of pulses that occur on *Pin* during the *Period* and stores the result in *Var*. *Pin* is automatically made an input. *Pin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0). In this project, the PORTB pin2 is used for the input pulse. The resolution of *Period* is in milliseconds. It tracks the oscillator frequency based on the **DEFINE** OSC. **COUNT** checks the state of *Pin* in a tight loop and counts the low to high transitions. With a 4MHz oscillator it checks the pin state every 20us. With a 20MHz oscillator it checks the pin state every 4us. Therefore, in this project, the 8MHz oscillator will check the pin state every 10µs. From this, it can be determined that the highest frequency of pulses that can be counted is 25KHz with a 4MHz oscillator and 125KHz with a 20MHz oscillator, if the frequency has a 50% duty cycle (the high time is the same as the low time).

COUNT PORTB.2, 1, HIGH_1 ‘count the pulse in into PORTB pin2 in 1miliseconds

5.1.2.5 IF…ELSE

IF..ELSE/THEN performs one or more comparisons. Each *Comp* term can relate a variable to a constant or other variable and includes one of the comparison operators listed previously. **IF..THEN** evaluates the comparison terms for true or false. If it evaluates to true, the operation after the **THEN** is executed. If it evaluates to false, the operation after the **THEN** is not executed. Comparisons that evaluate to 0 are considered false. Any other value is considered true.

IF..THEN cannot be used to check if a number is less than 0. It is essential to use parenthesis to specify the order in which the operations should be tested. Otherwise, operator precedence will determine it for you and the result may not be as expected. **IF..THEN** can operate in 2 manners. In one form, the **THEN** in an **IF..THEN** is essentially a **GOTO**. If the condition is true, the program will **GOTO** the label after the **THEN**. If the condition evaluates to false, the program will continue at the next line after the **IF..THEN**. In the second form, **IF..THEN** can conditionally execute a group of *Statement*s following the **THEN**. The *Statement*s may be placed after the **THEN** or may be on another line and followed by an optional **ELSE** and non-optional **ENDIF** to complete the structure. In this project, the command of second term of **IF..ELSE** is used.

```
IF HIGH_1 <= 10 THEN
   high portb.0
   high portb.1
   high portb.3

ELSE
   low portb.0
   low portb.1
   low portb.3

ENDIF
```

5.2 MicroCode Studio (PicBasic Compiler)

5.2.1 An Overview

MicroCode Studio is a powerful, visual Integrated Development Environment (IDE) with In Circuit Debugging (ICD) capability designed specifically for microEngineering Labs PICBASIC™ and PICBASIC PRO™ compiler. The main editor provides full syntax highlighting of your code with context sensitive keyword help and syntax hints. The code explorer allows you to automatically jump to include files, defines, constants, variables, aliases and modifiers, symbols and labels, that are contained within source code. Full cut, copy, paste and undo is provided, together with search and replace features. MicroCode Studio now includes EasyHID Wizard, a free code generation tool that enables a user to quickly implement bi-directional communication between an embedded PIC™ microcontroller and a PC. The benefits of using Microcode Studio as an assembler are:

- Full syntax highlighting of your source code
- Quickly jump to include files, symbols, defines, variables and labels using the code explorer window
- Identify and correct compilation and assembler errors
- View serial output from your microcontroller
- Keyword based context sensitive help
- Support for MPASM

The compiler, assembler and programmer options is easy to setup. Compilation and assembler errors can easily be identified and corrected using the error results window. Just click on a compilation error and MicroCode Studio will automatically take to the error line. MicroCode Studio even comes with a serial communications window, allowing the debugging and view serial output from your microcontroller. Each line of source code is animated in the main editor window, showing which program line is currently being executed by the host microcontroller. User also can even toggle multiple breakpoints and step through your PICBASIC PRO™ code line by line.

5.2.2 MicroCode Studio Editor

The MicroCode Studio Compiler is one of the PicBasic Compilers that available for the Microchip PIC Controllers which is in this project, PIC 16F877. The MicroCode Studio Compiler is a superb compiler and is designed to run under Windows 95, 98, ME, NT4, 2000 or XP. MicroCode Studio Compiler is accessed through its Integrated Development Environment (IDE) that allows users to build projects, add source code files to the projects, set compiler options for the objects and compile projects into executable program files.

The MicroCode Studio Compiler has its own database to track the properties of each Microchip PIC Microcontroller that it supports which is in this project is the PIC 16F877. The data base can be update through Device Editor Menu item and new devices may be added or change the entries for a device for a special application.

To construct a PicBasic program using MicroCode Studio Compiler, all project file must have a ***.pjt*** extension. At one time, only one source file is directly assigned to each project. As an example, in this project, PIC 16F877 Microcontroller functioned as a microcontroller that controls the flow of the operation. Additional statement must be included in the program by the PIC selection toolbar.

Every new program can be created manually using File\New menu item or it can be generated by the PIC Wizard utility using Project\New\PIC Wizard that can help generate code for I/O, Timers, Usart automatically. To create a new project using a MicroCode Studio Compiler, it is convenience and reliable to set it up trough PIC Wizard. PIC Wizard will lead users to a proper setup in choosing the specific device, oscillator frequency, and function generation. There are 4 steps to create the workspace and PBP project file.

Step 1, (Figure 5.1) New - Creates a new document. A header is automatically generated, showing information such as author, copyright and date. To toggle this feature on or off, or edit the header properties, you should select editor options.

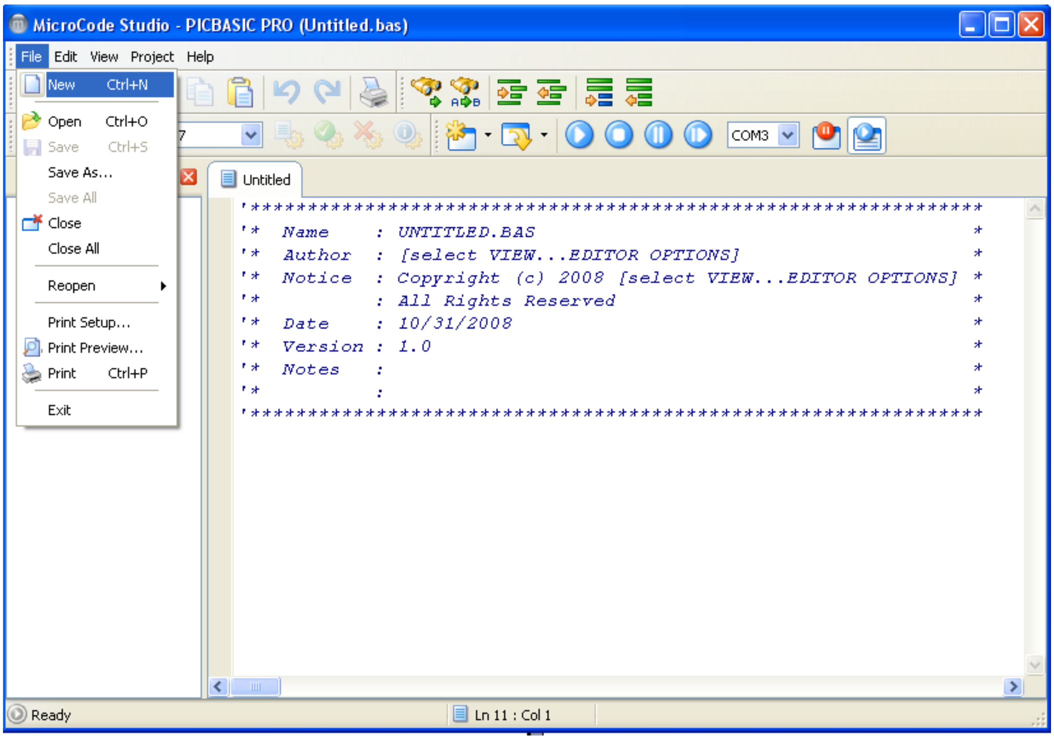


Figure 5.1: Select New File

Step 2 (Figure 5.2) When a new document is created, the default target processor device is set to the 16F877. To change the default, edit the file 'default.ini', located in your main installation folder. It is a need to restart MicroCode Studio after making the changes.

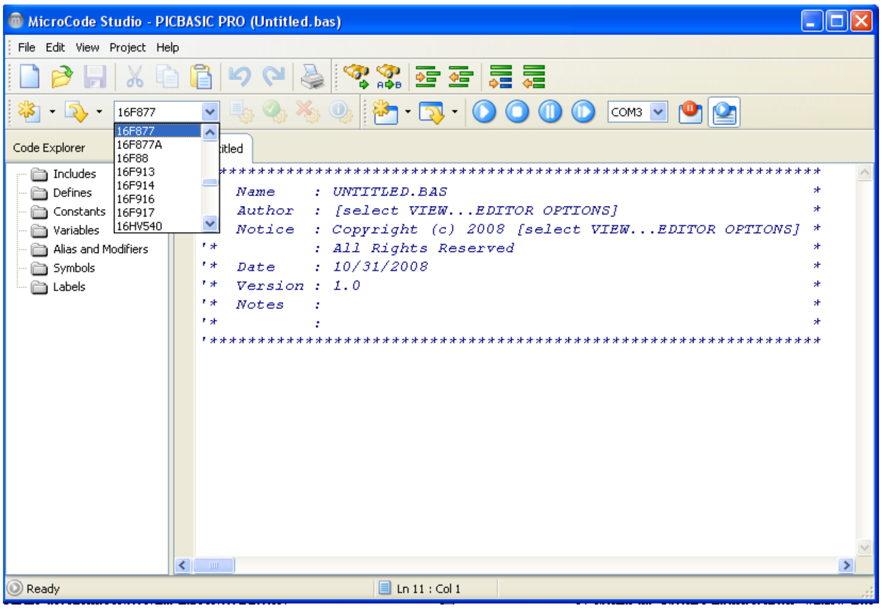


Figure 5.2: Select Device suite

Step 3, real program must be saved in a specific file name. It is important to verify Language Tool suite, Active Tool suite and location of the file so that project wizard may refer to it and to select the tool suite. Project directory and Project named need to be specified and assigned as shown in Figure 5.3. In this tab, Project directory is referring to C document files while project name is assigned as BODY DETECTOR.

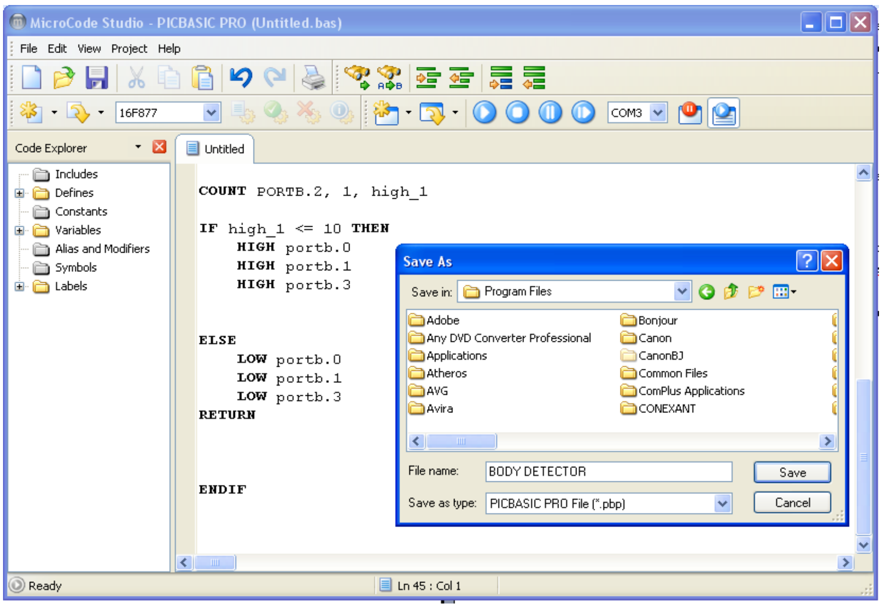


Figure 5.3: Assign Project Name and Project Directory

Step 4 is to add any existing files to the project. All type of files may be created in the PBP software simulator such PicKit 2. Others files such as .asm, .COD, .LST, .MAC, .XRF, and .HEX files also can be included for an external applications and this can be achieved by just clicking an open files button at the directory folder as shown in Figure 5.4. In this project, .HEX file is a must to undergo the programming process.

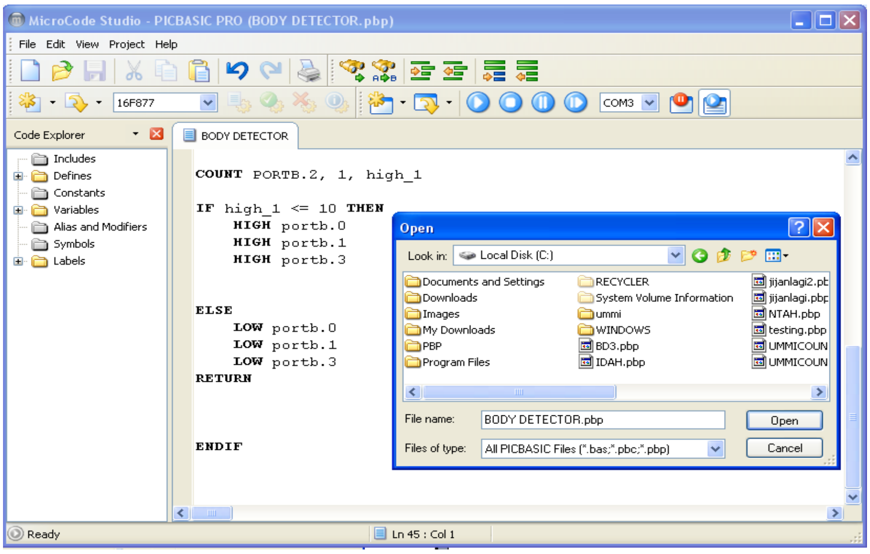


Figure 5.4: Add existing file

Step 5 (Figure 5.5) and final step, after all programming is written, compile the program. And if no errors occurred, the assembly compiling is successful.

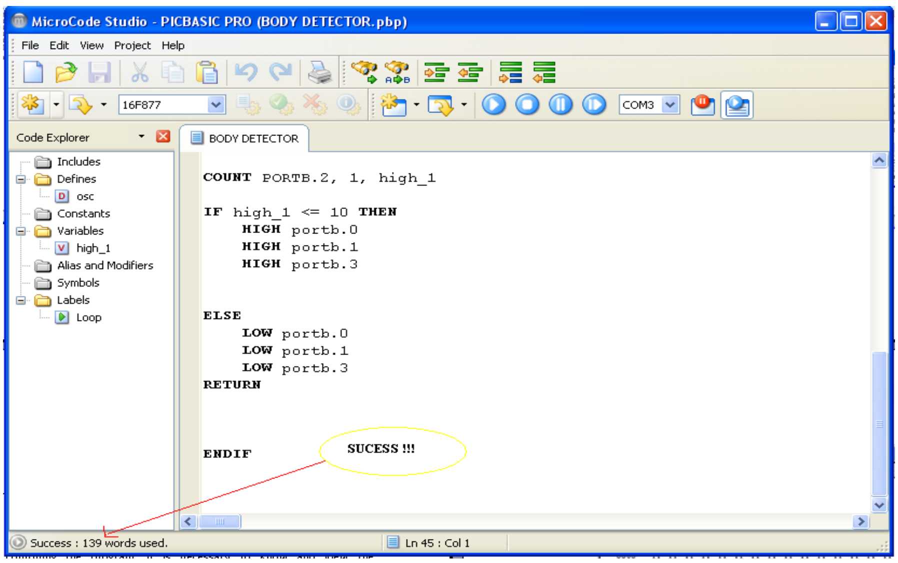


Figure 5.5: Compiling the program

5.3 MICROCHIP PicKit 2

5.3.1 An Overview

Microchip Technology Inc., a leading provider of microcontroller and analog semiconductors, today announced that the popular PICkit(TM) 2 development programmer now supports in-circuit debugging of selected PIC(R) microcontroller products. This enables users to have development and evaluation with PIC microcontrollers for a very low initial investment. PICkit 2 Debug Express Kit features a 44-pin demo board populated with a PIC16F917 microcontroller, and connects to any personal computer via USB. Its in-circuit debugging features include halt, single step and setting a breakpoint. PicKit also included are 12 easy-to-understand tutorials that allow users to learn at their own pace (source code provided).

5.3.2 Using PicKit 2

After compiling the program, it is necessary to know and view the microcontroller condition such as the state of the microprocessor, the counters, the stack pointers and the input/output condition pins. All this information can be gained by opening the Microchip PicKit 2 software after compiling the program. Information such as name of the ‘Special Function Register (SFR) in hexadecimal, decimal, binary and ASCII representations will be displayed. This information will be updated in File Register when the debugger executing the program. To get started, Start the PICkit™ 2 Programming Software by selecting *Start > Programs > PICkit 2 Microcontroller Programmer > PICkit 2*. The programming interface appears as shown in Figure 5.6

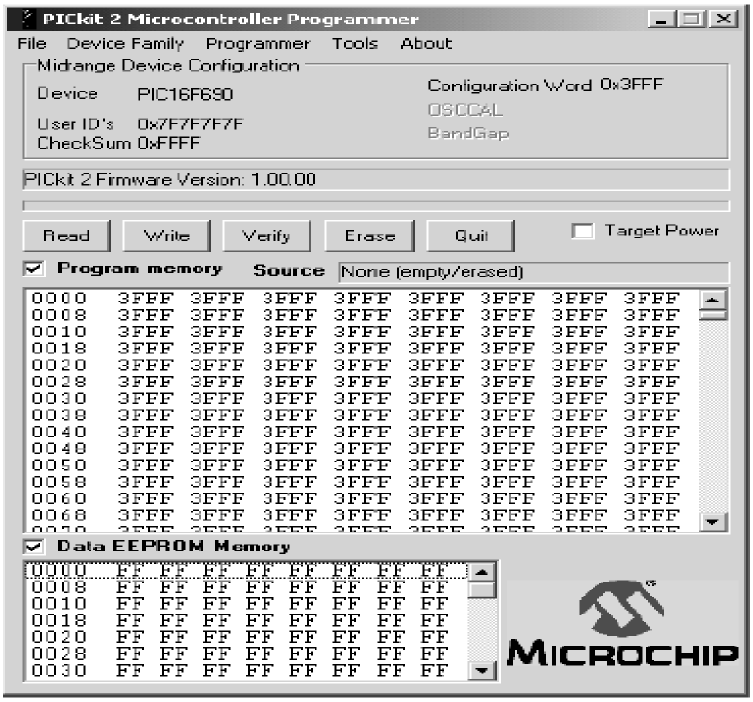


Figure 5.6: PicKit 2 Programming Software

The PICkit 2 Microcontroller Programmer is capable of programming a variety of Flash-based Microchip PICmicro® microcontrollers. Next afterwards, the device selection and identification is done (Figure 5.7).

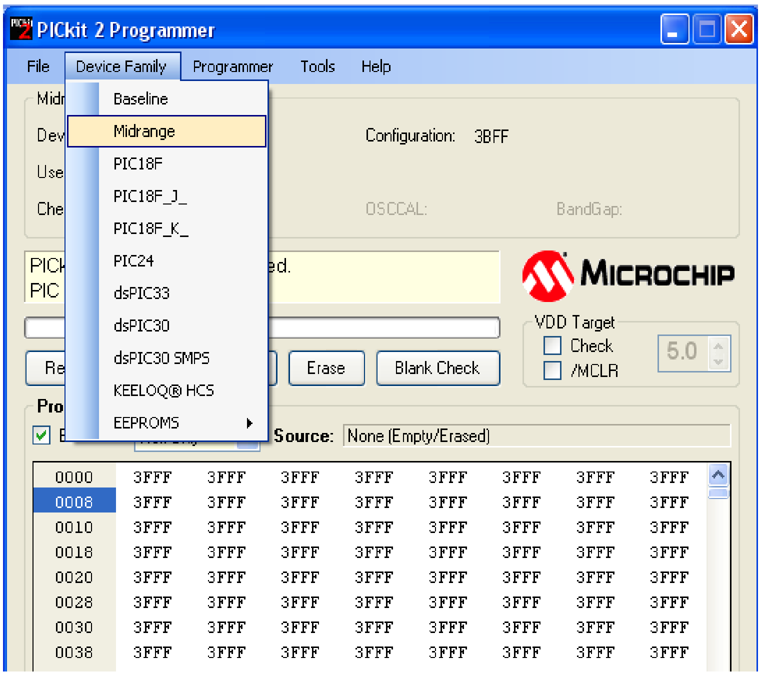


Figure 5.7: PicKit 2 Selection Device

Next, is to import the HEX file from the successful compiling in Microcode Studio in the same directory. To import a compiled program (hex file), select *File > Import HEX* as shown in Figure 5.8. Browse for the hex file and click **Open**. The code is displayed in the Program Memory and EE Data Memory windows. The name of the hex file is displayed in the Source block.

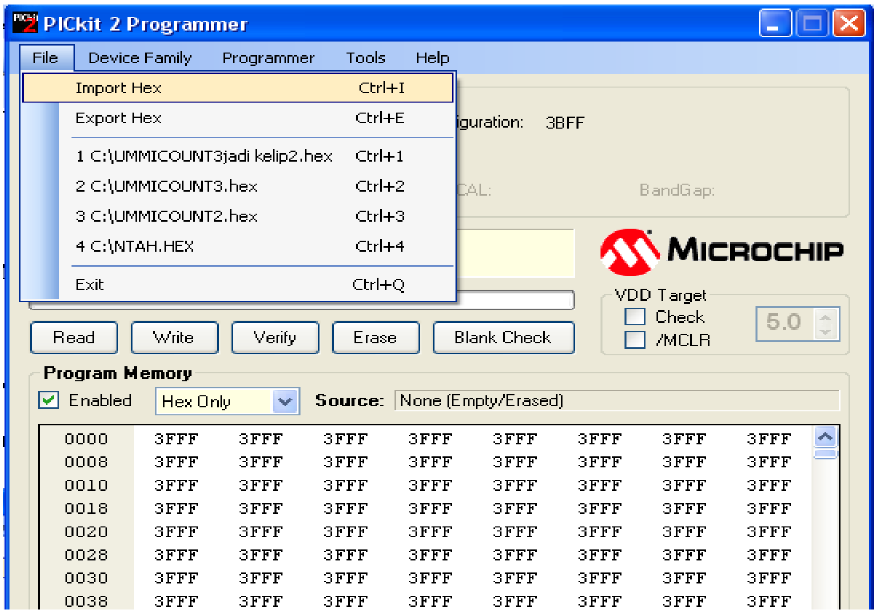


Figure 5.8: PicKit 2 Import Hex File

Figure 5.9 shows program memory when the Hex file is imported.

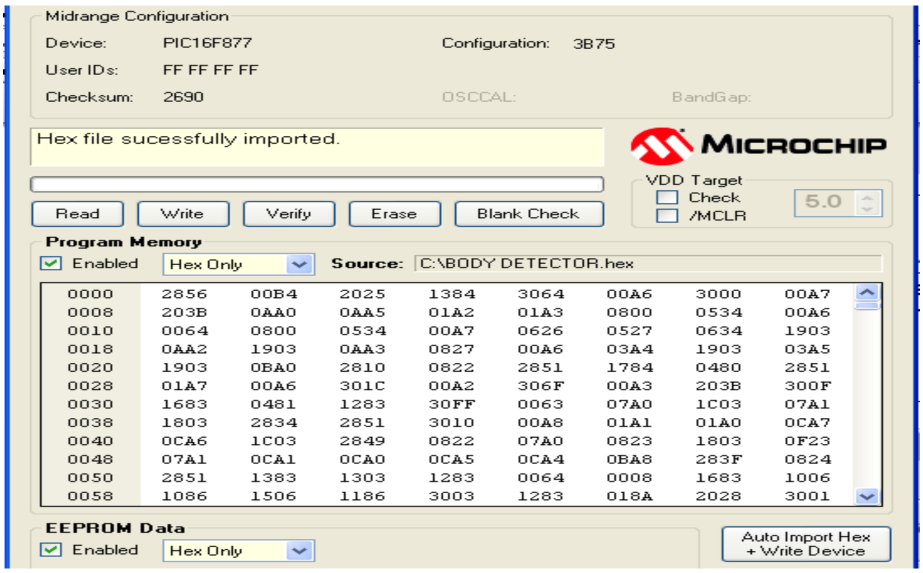


Figure 5.9: Program Memory

After a device family has been selected and a hex file has been imported, the target PICmicro MCU can be programmed by clicking on the **Write** button. The PICmicro MCU will be erased and programmed with the hex code previously imported (Figure 5.10). The status of the Write operation is displayed in the status bar located under the Device Configuration window.

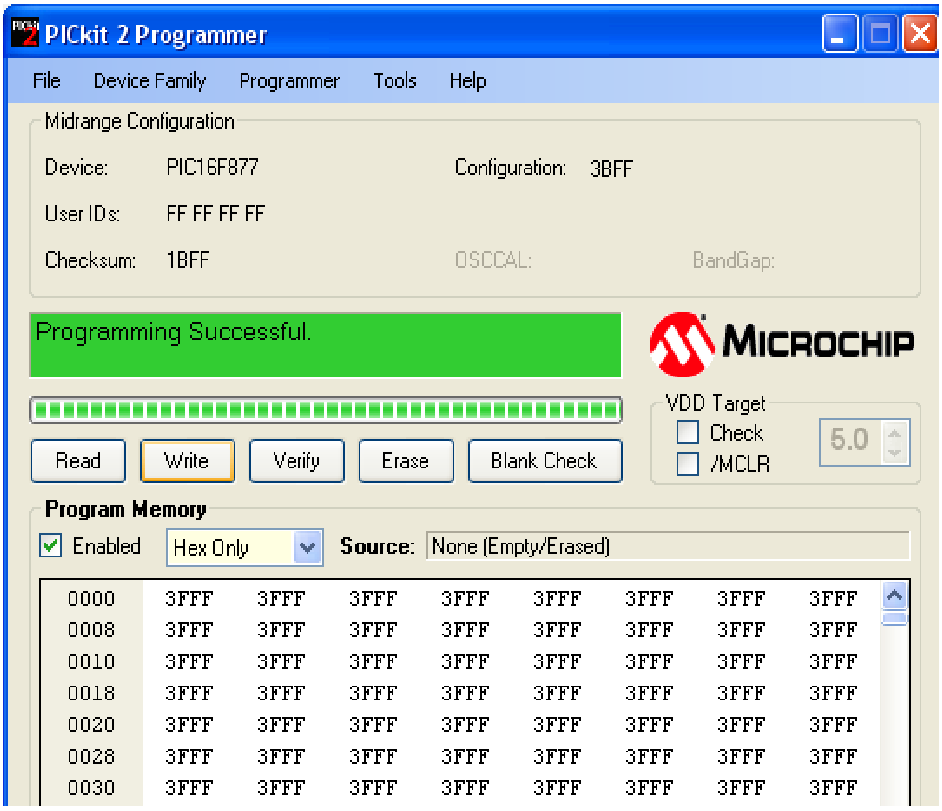


Figure 5.10: Write Successful Status

5.4 Programming the PIC 16F877 Microcontroller

After developing the Alarm System Using Body Detector program, it's really important to check either the program is working or not. The easiest way to find it out is trying and testing the code again and again using Microchip Pickit Programmer. It does take a long time to develop a program that really satisfies the project objective and scope. The flash memory technology of the PIC 16F877A microcontroller permits the microcontroller to be programmed, erase and programmed again repeatedly and it saves us more time to construct ideal program. To program the PIC 16F877 (Figure 5.11), it only takes merely 3 seconds. By clicking Program button, the program will be automatically downloaded into PIC and the PIC chip is ready to perform a working system and control the security application.

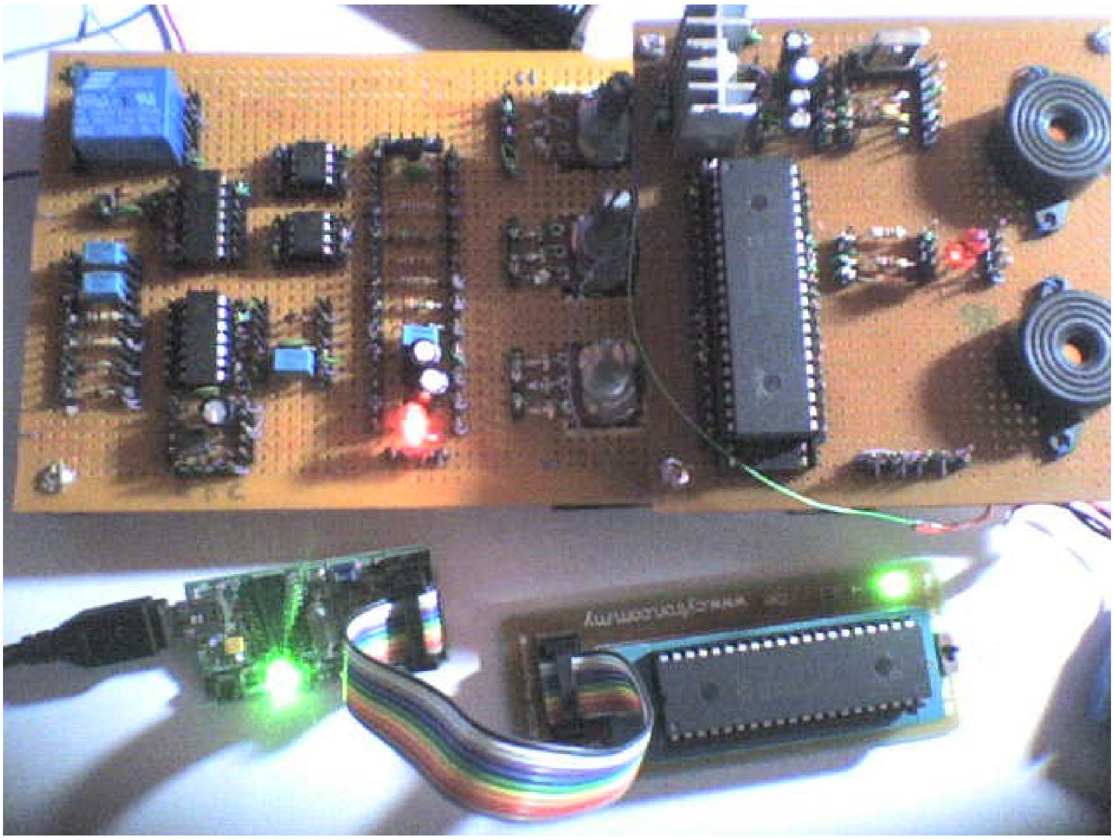


Figure 5.11: Programming the PIC 16F877 Microcontroller

CHAPTER 6

RESULT & DISCUSSION

6.1 INTRODUCTION

In this chapter, all results and the limitation of the project will be discussed. All discussions will focus on the result obtained and performance of the project.

6.2 BODY DETECTOR

6.2.1 Body Detector Output

In the construction of Body Detector circuitry, there are 2 main outputs that need to be taken into consideration of completing the project which are the output from IC1b pin9; triggering and non-triggering state.

The output of IC1a pin5 is fed to the trigger input of IC1b. Therefore astable IC1a triggers monostable IC1b. However it is the way in which IC1b is triggered that is important. Supposed that the monostable timer IC1b goes ‘low’ for a duration fractionally longer than the period of astable IC1a (with IC1b triggered by the trailing edge from IC1a). Therefore, IC1b will miss the next trailing edge from IC1a and will only be triggered by the following trailing edge.

If then a body comes near, the frequency of IC1a will drop, therefore the monostable timer IC1b will go ‘low’ for duration fractionally ‘longer’ than the period of astable IC1a.The result is the sharp negative-going edge pulses (Figure 6.1) when the Body Detector sense no presence of human body, while the wider positive going edge pulses (Figure 6.2) appear when the Body Detector sensed the presence of human body approaches. It need hardly be said that these two very different waveforms will have significantly effect on a standard charge pump. Therefore, a minute variation at IC1a pin5 results in very significant difference at IC1b output pin9.

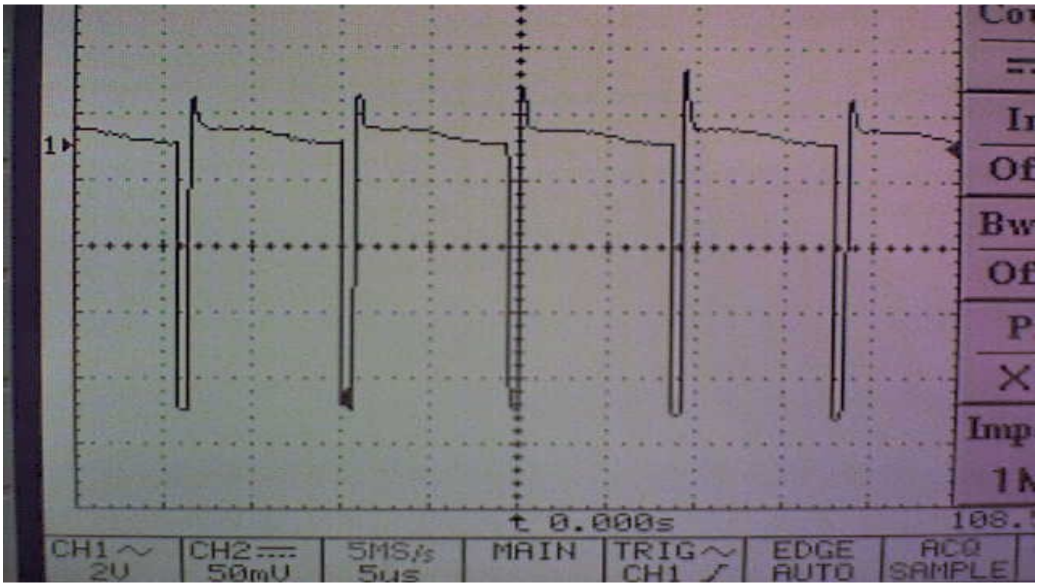


Figure 6.1: Non-triggerable state (no human body detection)

Figure 6.2: Triggerable state (human body detection)

Below is the analysis of the output from Body Detector measured by the calibrated oscilloscope and all the analysis is based on the IC1b pin9. The changes in frequency will be great affect for the accomplishment for this project as though that this changes will have significant effect on the programmable part. In Table 6.1 is the analysis of the output pulses.

Table 6.1: Analysis of the output pulses

Variable	Non-triggerable state	Triggerable state
Frequency	±180kHz	±20kHz
Time settling	2.5μs	2.5μs
Voltage drop	5V	5V

6.2.2 Setting up

Setting up may require a little patience, but it should not be difficult because several components need to checked the status whether the part of circuitry is functioned or not.

The best way to adjust the circuit is to use an oscilloscope. IC1b pin8 is attached with the probe and take glance at the period on the oscilloscope, which will eventually more or less match the period time of IC1b. This waveform should show negative going pulses as seen in Figure 6.1. Then touch the probe to IC1 pin 9, and start turning up preset VR3 (clockwise). The positive-going pulses will gradually widen, until they turn into very narrow negative going pulses. Then suddenly a more or less balanced square wave will bounce onto the screen. Touch the sensor, and the wider positive-going pulses will reappear. Now adjust preset VR4 so that LED D4 illuminates and the relay clicks when the narrow negative-going pulses appear. Note that if VR4 is turned up too high (too far *anticlockwise*), the circuit will be needlessly susceptible to transients. Adjustment with a multimeter is equally straightforward. Monitor the voltage at the positive plate of capacitor C6, and slowly turn up VR3. The voltage should gradually rise to above 6V, then suddenly plunge to somewhere over 5V. This "plunge" amounts to about 1V or a little more. Measure the voltage at IC2 pin 3, and adjust it (via VR4) to about 0·3V higher than the voltage measured after the "plunge" referred to above. When the sensor is now touched, LED. D4 should illuminate. If a different sized sensor is used, or if a sensor is moved about, preset VR3 will likely require readjustment. If there is a significant difference in the mass of sensors used, VR4 might need readjusting also. If the Body Detector is attached to a new sensor, and the set-up above has already been completed, VR3 may be turned right back (anticlockwise), then turned up (clockwise) until LED D4 illuminates, continuing until D4 just goes out again. The rest is fine-tuning.

Bear in mind that the circuit might be affected by our own body capacitance during adjustment, so that one might need to stand back between adjustments to check how it is going. Ideally, one would use a screwdriver with an insulated shaft. Also bear in mind that the circuit might need to settle after initial adjustment. Come back to it more than ten minutes later to recheck the adjustment.

6.2.3 Switching On

Since the Body Detector is intended to detect any and all body presence, an on/off switch battery (Figure 6.3) that is mounted close to the circuit could in some instances present a problem. At the same time, to include any delays in triggering might be self-defeating, since some applications will require an instant triggering. Therefore, the delay in programming is o solution to this problem. In my applications, this did not cause the circuit to trigger when switching off. The insertion of delay is left until the other circuit is complete and is found to be working satisfactorily.

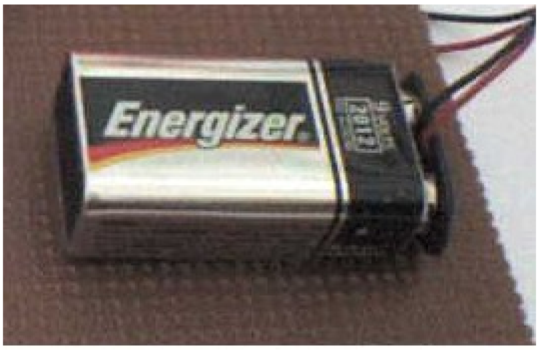


Figure 6.3: Battery Switching On

6.2.4 Casing Up

The Body Detector is built on a metal case with slotted walls, size 230mm x 150mm x 75mm approximate (Figure 6.4). Holes are prepared on the bottom of the case for attachment of sensor. Two small holes are also carefully positioned on top of the case to expose the sound of buzzer, so these may easily be heard from outside the case. It is suggested that the hole for the attachment sensor is carefully screwed. Cable ties may be used to tidy up the connecting wires. The 9V alkaline battery is ensured that in secure position, since a change in its position inside the case could slightly affect the main unit's calibration. The internal layout of prototype model and type of metal sensor used in this project is shown at Figure 6.5 and Figure 6.6

Figure 6.4: View of the completed Body Detector

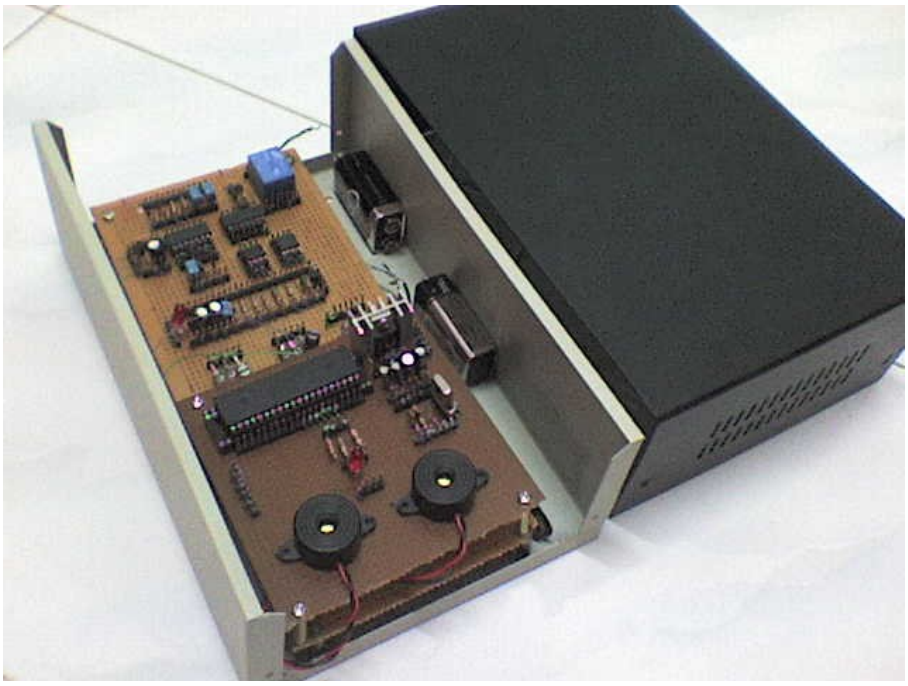


Figure 6.5: Internal layout of the prototype model

Figure 6.6: Type of metal sensor; tin foil and metal

6.3 PIC 16F877 MICROCONTROLLER

6.3.1 PIC 16F877 OUTPUT

The PIC 16F877 is considered the actuator of completing this project. With the advanced programmed of delay, counting the pulses in the input port, condition session and activate the flows of alarm system, this whole process will produced the desired alarm system. Starting with the status checking of PIC 16F877 microcontroller, the voltage drop at PIC 16F877 pin11 will be measured by using multimeter and the result is 5V. This value ensured that the PIC 16F877 will function properly and this value also were produced by the regulating voltage supply through the power supply circuitry mentioned in Chapter 4. A sound buzzering and red LED illuminating will be triggered when there is the presence of human body detection. This whole processed dependable on the structured program created and is being fed from IC1b pin9 into the input of pin2 PORTB PIC 16F877.

6.4 IN USE

All in all, it is sensible to adjust the Body Detector so that it is sensitive enough to safely trigger, yet not so sensitive that it comes too close to its trigger threshold, which may lead to false triggering, particularly with temperature variations. A distance of 100 mm represents a dependable range for a lightweight sensor such as sheet of tin foil. Also must take any consideration of interest, as well as testing the outer limits of the circuit.

The Body Detector itself must be located in a place where it is relatively immune to body presence. Once initial setting-up has been completed, and if the unit and sensor are not moved about, we should require no more than a little adjustment of the potentiometers for long-term and reliable service.

A wide variety of metal sensor may be tried. However, that each time the sensor is exchanged, this is likely to require quick re-calibration of the Body Detector. Always be sure to make a secure connection between the unit and sensor. User can also try different sizes of tin foil. User may also experiment with larger objects such as bicycle or fridge door which should serve quite well as sensors. In the case of heavy metal items, a lighter sensor (insulated wire included) may usually be mounted on their surface, without any physical connection to the metal object, to far better effect.

When Body Detector is attached to a metal object, whether to a pin or others, the entire object to which it is attached is sensitized. For instance, if it is attached to the handlebars at the bicycle, it will reliably picking up fingers touching a rear wheel. Only those parts of the bicycle which are insulated from the whole, for instance, or even loose bolts will not be sensitized. Having said this, an object need not always have physical contact with the Body Detector's sensor to become an extension of the sensor. Finally, with the proper adjustment, nobody should be able to slip undetected past the Alarm System Using Body Detector (Figure 6.7).

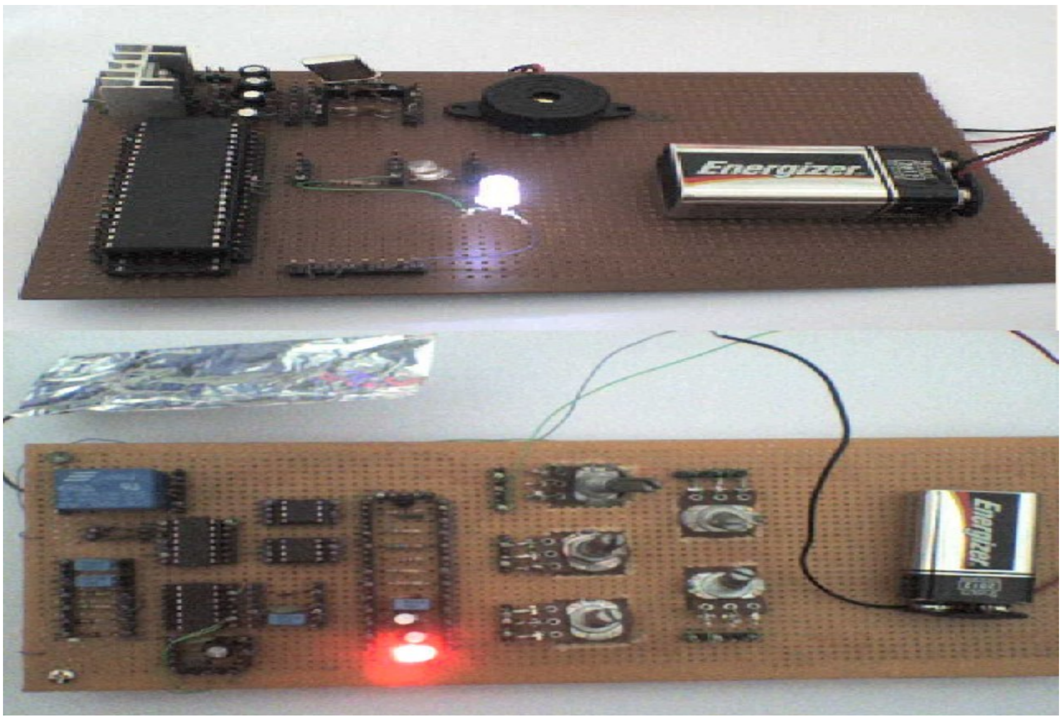


Figure 6.7: Complete Alarm System Using Body Detector

6.5 RECOMMENDATIONS FOR THE PROJECT

This topic discusses the recommendations on the problems that exist in Alarm System Using Body Detector. In general, the discussion involves the whole of Alarm System Using Body Detector parts. The problems and the recommendations discussed here are focused more on the limitation of the feedback and cost to user.

6.5.1 Components Configuration

In Body Detector circuit, there are several problems that affecting the functionality of main unit which is the fault error handling on the component's configuration. Components such as potentiometer, relay and sensor contribute big challenge in completing this project. The pin arrangement in potentiometer confused the connection because potentiometer is a device/ tools that measured both linear and angular displacement. With the three-terminal resistor with a sliding contact that forms an adjustable voltage divider, the connection seems confused to converts position information into a variable voltage through a resistor. While the relay problems was the internal connections of contacts. A relay is an electrical switch that opens and closes under the control of another electrical circuit. The connection of relay towards the other electrical circuit which is this project was the TR2 BC549 small signal transistor becomes big issues in order to perform the detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers and perform logic functions. Lastly the uses of sensor (in this case is a sheet of tin foil), which is not sensible to drop a voltage when a human body approaches it. It was probably being affected by the surface area of sensor and other variation of temperature and environmental factor. The best solution for all the problems of error in handling the component's configuration is refers to many researches and configures the components using the try and error method on the board.

6.5.2 Unstable Board

The Body Detector circuitry is very easy to get unstable due to lots of changing variations such as the temperature selectivity and the sensor sensitivity. Stability is the challenge for the sensitivity. This is essentially because this quantify that the circuit measures; in this case is body capacitance which is so extremely small that minute variations within the circuits itself to swamp the quantity being measured. The importance of achieving a high order of stability still remains a significant problem at the end of the day and the final circuit exhibits a high degree of stability. It is recommended in the solution that Body Detector will need to orderly adjusted the be preset the potentiometers due to changes variation by using analysis method when configuring the effect of ranges in potentiometer and the contact connections related to external circuit.

6.5.3 Programming

Programming PIC 16F877 microcontroller would not be difficult but to complete desired applications, the programming may require lot of effort; redo and focused. At first stage, the command PULSIN was used to capture the input pulse frequency into PIC 16F877 considerations. PULSIN measures pulse width on *Pin*. If *State* is zero, the width of a low pulse is measured. If *State* is one, the width of a high pulse is measured. The measured width is placed in *Var*. If the pulse edge never happens or the width of the pulse is too great to measure, *Var* is set to zero. *Pin* is automatically made an input. The resolution of PULSIN is dependent upon the oscillator frequency. If a 4MHz oscillator is used, the pulse width is returned in 10us increments. If a 20MHz oscillator is used, the pulse width will have a 2us resolution. Defining an OSC value has no effect on PULSIN. The resolution always changes with the actual oscillator speed. PULSIN normally waits a maximum of 65535 counts before it determines there is no pulse. Therefore, Body Detector is not suitable to use PULSIN command to execute the system flow on considering the measurement of pulse width make the system confused because the time settling in the output pulse reached until 1200 pulse in a milliseconds. Therefore, it is impossible to apply PULSIN command into programming considerations. The best solution is by using the Count command which count the number of pulses that occur on *Pin* during the *Period* and stores the result in *Var*. It tracks the oscillator frequency based on the DEFINE OSC. COUNT checks the state of *Pin* in a tight loop and counts the low to high transitions. Therefore, Body Detector's pulses will be counted on *a var pin* during milliseconds and we can make the activation when changing counted pulses occurred. In Table 6.2 is the summarization of the limitation i have been through in completing this project and the solutions.

Table 6.2: Limitations and Solutions

No.	Problem(s)	Solution(s)
1.	Components Configuration	Try error method
2.	Unstable Board	Analysis method on preset potentiometers
3.	Programming capture pulses PULSIN command	Using programming count pulse COUNT command

6.6 ACCESS CONTROL AND POWER CONSUMPTION

Alarm System Using Body Detector involves the use of Body Detector device, PIC 16F877 microcontroller, and LED, buzzer to control the sensed of human body detection. Extra power supplies are needed to power up the PIC 16F877 and amplifying the applications. Batteries using are not capable of supplying enough current to drive the DC motor (unless if want to use as an actuator of applications). If the battery cannot exceed 9V, it cannot produce enough current to drive the DC motor and the system may not work properly. The system is powered by constant power supply and must be turned on for 24 hours per day.

The best solution is to build another control equipment using PIC microcontroller to switch on application remotely before the user gain access through the unit. The control equipment is also connected to a relay, which functions to switch on the power supply for application. After the application is powered by constant power supply, it will be able to operate and perform security operation. Sufficient back up power supply (battery) also is important to make sure the system can work properly during power breakdown.

6.7 COST AND COMMERCIALIZATION

At a time of reduced budget resulting in many electrical appliances need to used, one way to increase efficiency and productivity of security is by using Alarm System Using Body Detector which will increase the safeties of individuals. The project components with the prices are shown at Table 6.3 and Table 6.4.

Table 6.3: The Body Detector Components Prices

No.	ITEMS	Quantity	Price per Unit	Price (RM)
1.	Resistor 1kΩ	3	0.05	0.15
2.	Resistor 68kΩ	3	0.06	0.18
3.	Resistor 100kΩ	1	0.10	0.10
4.	Resistor 2M2Ω	1	0.50	0.50
5.	Resistor 5k6Ω	1	0.25	0.25
6.	Potentiometer 100k	1	2.50	2.50
7.	Potentiometer 10k	1	2.50	2.50
8.	Potentiometer 500k	3	2.50	7.50
9.	Capacitor 4p7F	2	0.06	0.12

10.	Capacitor 10 nF	3	0.06	0.18
11.	Capacitor 100 Nf	5	0.06	0.30
11.	Capacitor 100μF	3	0.06	0.18
12.	Diode 1N4148	3	0.50	1.50
13.	Led	1	0.20	0.20
14.	Transistor 2N3819	1	3.30	3.30
15.	Transistor BC549	1	2.40	2.40
16.	CMOS 7556	2	3.80	7.6
17.	Transistor TL071CN	1	3.70	3.70
18.	CMOS 7555	1	3.20	3.20
19.	Relay	1	4.00	4.00
20.	Independent Board	1	5.00	5.00
21.	Stand-off pillars	4	0.20	0.80
22.	Battery clip	2	0.20	0.40
23.	Tin foil			1.00
24.	Battery	1	5.00	5.00
			TOTAL	**RM 52.56**

Table 6.4: The PIC16F877 Components Prices

NO.	ITEMS	Quantity	Price per Unit	Price (RM)
1.	PIC16F877	1	22.00	22.00
2.	7805 Voltage Regulator	1	1.20	1.20
3.	Crystal 8Mhz	1	2.00	2.00
4.	Resistor 10kΩ	3	0.05	0.15
5.	Capacitor 12pF	2	0.06	0.12
6.	Capacitor 10µF	2	0.06	0.12
7.	Capacitor 1µF	2	0.06	0.12
8.	LED	2	0.50	1.00
9.	Buzzer	2	4.90	9.8
10.	Independent Board		5.00	5.00
11.	Battery	1	5.00	5.00
12.	Stand off pillars	4	0.20	0.80
13.	Battery Clip	2	0.20	0.40
			TOTAL	**RM 47.71**
			ALL TOTAL	**RM 100.27**

From the Table 6.3 and 6.4, the total price for Alarm System Using Body Detector is RM 100.27. This price would be much lower if the production of this project is higher because the single components prices will be lower. Besides, RM 10.00 will be cut from the exact prices shown because the battery is not being provided by the production, but must be provided by users. Alarm System Using Body Detector can be commercialized due to several reasons which are:

i) The selling prices will be lower than RM 90.00
ii) Portable alarm system
iii) Small in size and weight
iv) Simple interface with users

With these, Alarm System Using Body Detector would be the best portable alarm system that most of people want to grab.

CHAPTER 7

CONCLUSION AND FUTURE DEVELOPMENT

7.1 INTRODUCTION

This chapter discuss about the conclusion and project development in the future. This project has two major parts which is hardware description and software implementation. Both topics integrate with each other to develop Alarm System Using Body Detector as a working product that can be applied to perform effective security system.

7.2 CONCLUSION

As a conclusion, there are seven chapters which are introduction, literature review, methodology, hardware development, software implementation, result, discussion and the conclusion and future development that has been discuss in this thesis for the development of Alarm System Using Body Detector project.

The implementation of this project was successful since the main objective has been achieved. Alarm System Using Body Detector has ability to perform effective operation in the real world. The main heart of Alarm System Using Body Detector is main unit of Body Detector which produce significantly changes when there is absence or presence of human body approaches. This likely to give way to PIC 16F877 Microcontroller which acting as an actuator that controls the pulses communication with the Body Detector unit and powered up the security application.

Through simple analog RF technology, appropriate architecture design, 16F877 PIC Microcontroller and PicBasic Programming, the new world of body detection technology may help us increased security and reducing human intervention in the security field.

7.3 FUTURE DEVELOPMENT

For the future development, this project may lead to development of Body Detector network online systems that can be used to grant access authorization of a large number of computers. Company or organization may have a great security system as all workers need to pass through only few main entrances equipped with Body Detector network online system to the building. In this system, all terminals are connected to a central computer. By applying this system, security area can be protected against undesired access.

More or less for the Body Detector construction, using printed Circuit Board will be much likely saving the risk of stability. By having PCB in Body Detector construction, the probability of gaining high stability is positive. Besides, PCB makes the circuit become smaller and looks compact, this way, will increasing the thought to make this alarm system becomes a portable device.

This project could use more modes of operations. It includes the extension of the sensor by conductive materials and second by the extension of the sensor by human body. If the positive plate of the timing capacitor C is attached to a metal sensor, this makes it more receptive to the body's electric field. This sensor may have several modes of operations. For the extension of the sensor by conductive materials, a conductive object is placed on top of a sensor plate (e.g. a drink tin) as shown in Figure 7.1. This object then becomes an extension of the sensor. This could be useful to protect a valuable or dangerous object. More interesting still, some insulating materials is placed between a sensor plate and the conductive object. A book is shown in Figure 7.2, since paper serves as a good insulator. If the circuit is suitably adjusted, the object on top of the insulator will serve as an extension of the sensor, even though it is not physically connected to it. Now consider that the book is replaced with a tablecloth, or even a tabletop, and a silver dinner service is placed on top. The dinner service is now protected by the Detector, without the need for any wired connections, and without any "electronics" being evident. This could be useful, among other things, and for protecting items on shop shelves. A variation of Figure 7.3 which is an unusual one, yet it works, and may have some interesting applications. The human body itself may become an extension of the sensor plate. In this case, a second human body which approaches the first will trigger the circuit.

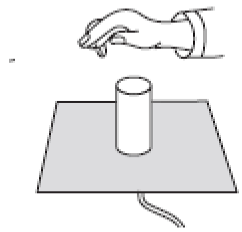


Figure 7.1: Extension of the sensor using conductive material

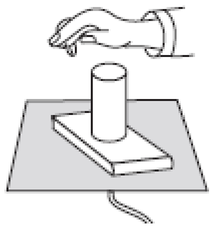


Figure 7.2: Extension of the sensor using conductive material with insulator

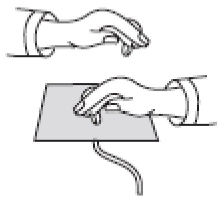


Figure 7.3: Extension of the sensor using human body

Considering the complexity of integrating new technology to produce a working system, I felt that my project was both challenging and innovative. The project touched a variety of engineering field including hardware implementation, understanding new breed of technology, develop body detection through capacitance theory protocol, writing and testing software. Hopefully with future innovations and research, this particular system can become the backbone for other researchers' fields of study.

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APPENDICES

APPENDIX A: Code Listing

```
'***********************************************************
'*  Name    : ALARM SYSTEM USING BODY DETECTOR.BAS
*
'*  Author  : UMMI KALSOM NOOR DIN]                 *
'*  Notice   : Copyright (c) 2008 [select VIEW...EDITOR OPTIONS] *
'*              : All Rights Reserved                          *
'*  Date      : 10/15/2008                                 *
'*  Version  : 1.0                                        *
'*  Notes    :                                          *
'*              :                                          *
'***********************************************************

define osc 8          'due to 8MHz crystal



trisb.0 = 0        'set as output for LED
trisb.1 = 0       'set as output for BUZZER
trisb.2 = 1       'set as input digital(PULSE)
trisb.3 = 0       'set as output for BUZZER


high_1 var byte

SLEEP 3

Loop:

count PORTB.2, 1, HIGH_1

IF HIGH_1 <= 10 THEN
   high portb.0
   high portb.1
   high portb.3


else
   low portb.0
   low portb.1
   low portb.3
return



ENDIF
```

APPENDIX B

PIC 16F877 Datasheet

MICROCHIP

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

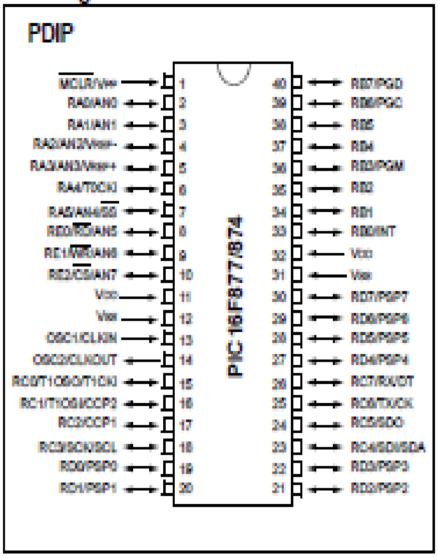
Devices Included in this Data Sheet:

- 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)

PIC16F87X

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.

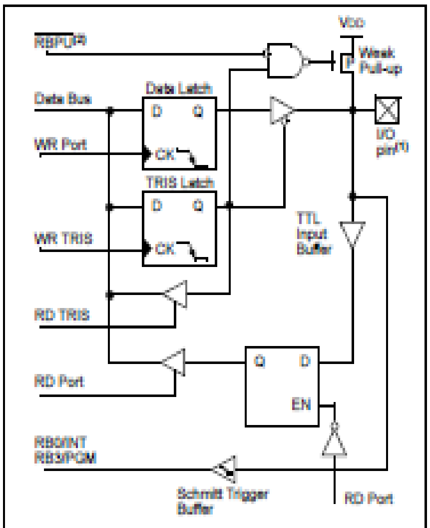
3.2 PORTB and the TRISB Register

PORTB is an 8-bit wide, bi-directional port. The corresponding data direction register is TRISB. Setting a TRISB bit (= 1) will make the corresponding PORTB pin an input (i.e., put the corresponding output driver in a Hi-Impedance mode). Clearing a TRISB bit (= 0) will make the corresponding PORTB pin an output (i.e., put the contents of the output latch on the selected pin).

Three pins of PORTB are multiplexed with the Low Voltage Programming function: RB3/PGM, RB6/PGC and RB7/PGD. The alternate functions of these pins are described in the Special Features Section.

Each of the PORTB pins has a weak internal pull-up. A single control bit can turn on all the pull-ups. This is performed by clearing bit $\overline{RBPU}$ (OPTION_REG<7>). The weak pull-up is automatically turned off when the port pin is configured as an output. The pull-ups are disabled on a Power-on Reset.

FIGURE 3-3: BLOCK DIAGRAM OF RB3:RB0 PINS



Note 1: I/O pins have diode protection to VDD and VSS.
2: To enable weak pull-ups, set the appropriate TRIS bit(s) and clear the $\overline{RBPU}$ bit (OPTION_REG<7>).

Four of the PORTB pins, RB7:RB4, have an interrupt-on-change feature. Only pins configured as inputs can cause this interrupt to occur (i.e., any RB7:RB4 pin configured as an output is excluded from the interrupt-on-change comparison). The input pins (of RB7:RB4) are compared with the old value latched on the last read of PORTB. The "mismatch" outputs of RB7:RB4 are OR'ed together to generate the RB Port Change Interrupt with flag bit RBIF (INTCON<0>).

This interrupt can wake the device from SLEEP. The user, in the Interrupt Service Routine, can clear the interrupt in the following manner:

a) Any read or write of PORTB. This will end the mismatch condition.
b) Clear flag bit RBIF.

A mismatch condition will continue to set flag bit RBIF. Reading PORTB will end the mismatch condition and allow flag bit RBIF to be cleared.

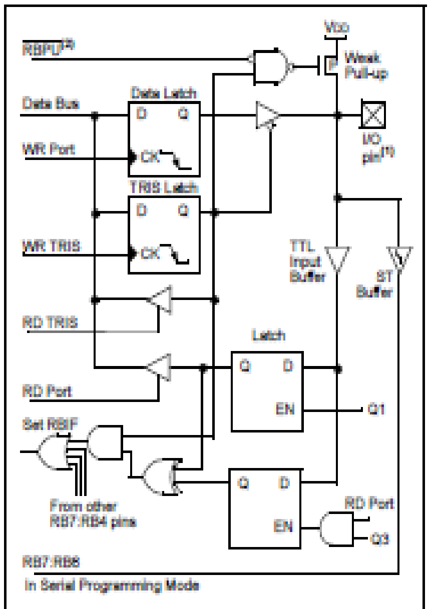
The interrupt-on-change feature is recommended for wake-up on key depression operation and operations where PORTB is only used for the interrupt-on-change feature. Polling of PORTB is not recommended while using the interrupt-on-change feature.

This interrupt-on-mismatch feature, together with software configureable pull-ups on these four pins, allow easy interface to a keypad and make it possible for wake-up on key depression. Refer to the Embedded Control Handbook, *"Implementing Wake-up on Key Strokes"* (AN552).

RB0/INT is an external interrupt input pin and is configured using the INTEDG bit (OPTION_REG<6>).

RB0/INT is discussed in detail in Section 12.10.1.

FIGURE 3-4: BLOCK DIAGRAM OF RB7:RB4 PINS



Note 1: I/O pins have diode protection to VDD and VSS.
2: To enable weak pull-ups, set the appropriate TRIS bit(s) and clear the $\overline{RBPU}$ bit (OPTION_REG<7>).

TABLE 3-3: PORTB FUNCTIONS

Name	Bit#	Buffer	Function
RB0/INT	bit0	TTL/ST(1)	Input/output pin or external interrupt input. Internal software programmable weak pull-up.
RB1	bit1	TTL	Input/output pin. Internal software programmable weak pull-up.
RB2	bit2	TTL	Input/output pin. Internal software programmable weak pull-up.
RB3/PGM(3)	bit3	TTL	Input/output pin or programming pin in LVP mode. Internal software programmable weak pull-up.
RB4	bit4	TTL	Input/output pin (with interrupt-on-change). Internal software programmable weak pull-up.
RB5	bit5	TTL	Input/output pin (with interrupt-on-change). Internal software programmable weak pull-up.
RB6/PGC	bit6	TTL/ST(2)	Input/output pin (with interrupt-on-change) or In-Circuit Debugger pin. Internal software programmable weak pull-up. Serial programming clock.
RB7/PGD	bit7	TTL/ST(2)	Input/output pin (with interrupt-on-change) or In-Circuit Debugger pin. Internal software programmable weak pull-up. Serial programming data.

Legend: TTL = TTL input, ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.

2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.

3: Low Voltage ICSP Programming (LVP) is enabled by default, which disables the RB3 I/O function. LVP must be disabled to enable RB3 as an I/O pin and allow maximum compatibility to the other 28-pin and 40-pin mid-range devices.

TABLE 3-4: SUMMARY OF REGISTERS ASSOCIATED WITH PORTB

Address	Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Value on: POR, BOR	Value on all other RESETS
06h, 106h	PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0	xxxx xxxx	uuuu uuuu
86h, 186h	TRISB	PORTB Data Direction Register								1111 1111	1111 1111
81h, 181h	OPTION_REG	RBPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0	1111 1111	1111 1111

Legend: x = unknown, u = unchanged. Shaded cells are not used by PORTB.

8.1 Capture Mode

In Capture mode, CCPR1H:CCPR1L captures the 16-bit value of the TMR1 register when an event occurs on pin RC2/CCP1. An event is defined as one of the following:

- Every falling edge
- Every rising edge
- Every 4th rising edge
- Every 16th rising edge

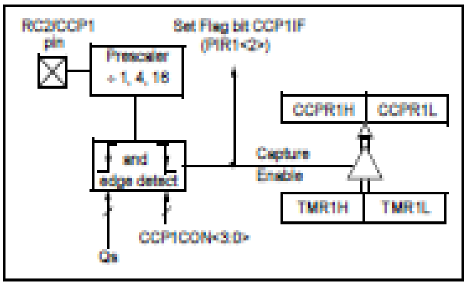
The type of event is configured by control bits CCP1M3:CCP1M0 (CCPxCON<3:0>). When a capture is made, the interrupt request flag bit CCP1IF (PIR1<2>) is set. The interrupt flag must be cleared in software. If another capture occurs before the value in register CCPR1 is read, the old captured value is overwritten by the new value.

8.1.1 CCP PIN CONFIGURATION

In Capture mode, the RC2/CCP1 pin should be configured as an input by setting the TRISC<2> bit.

Note:	If the RC2/CCP1 pin is configured as an output, a write to the port can cause a capture condition.

FIGURE 8-1: CAPTURE MODE OPERATION BLOCK DIAGRAM



8.1.2 TIMER1 MODE SELECTION

Timer1 must be running in Timer mode, or Synchronized Counter mode, for the CCP module to use the capture feature. In Asynchronous Counter mode, the capture operation may not work.

8.1.3 SOFTWARE INTERRUPT

When the Capture mode is changed, a false capture interrupt may be generated. The user should keep bit CCP1IE (PIE1<2>) clear to avoid false interrupts and should clear the flag bit CCP1IF, following any such change in operating mode.

8.1.4 CCP PRESCALER

There are four prescaler settings, specified by bits CCP1M3:CCP1M0. Whenever the CCP module is turned off, or the CCP module is not in Capture mode, the prescaler counter is cleared. Any RESET will clear the prescaler counter.

Switching from one capture prescaler to another may generate an interrupt. Also, the prescaler counter will not be cleared, therefore, the first capture may be from a non-zero prescaler. Example 8-1 shows the recommended method for switching between capture prescalers. This example also clears the prescaler counter and will not generate the "false" interrupt.

EXAMPLE 8-1: CHANGING BETWEEN CAPTURE PRESCALERS

```
CLRF    CCP1CON      ; Turn CCP module off
MOVLW   NEW_CAPT_PS  ; Load the W reg with
                     ; the new prescaler
                     ; move value and CCP ON
MOVWF   CCP1CON      ; Load CCP1CON with this
                     ; value
```

PIC16F87X

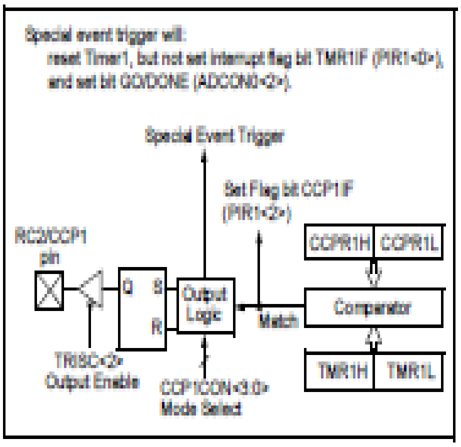
8.2 Compare Mode

In Compare mode, the 16-bit CCPR1 register value is constantly compared against the TMR1 register pair value. When a match occurs, the RC2/CCP1 pin is:

- Driven high
- Driven low
- Remains unchanged

The action on the pin is based on the value of control bits CCP1M3:CCP1M0 (CCP1CON<3:0>). At the same time, interrupt flag bit CCP1IF is set.

FIGURE 8-2: COMPARE MODE OPERATION BLOCK DIAGRAM



8.2.1 CCP PIN CONFIGURATION

The user must configure the RC2/CCP1 pin as an output by clearing the TRISC<2> bit.

> **Note:** Clearing the CCP1CON register will force the RC2/CCP1 compare output latch to the default low level. This is not the PORTC I/O data latch.

8.2.2 TIMER1 MODE SELECTION

Timer1 must be running in Timer mode, or Synchronized Counter mode, if the CCP module is using the compare feature. In Asynchronous Counter mode, the compare operation may not work.

8.2.3 SOFTWARE INTERRUPT MODE

When Generate Software Interrupt mode is chosen, the CCP1 pin is not affected. The CCPIF bit is set, causing a CCP interrupt (if enabled).

8.2.4 SPECIAL EVENT TRIGGER

In this mode, an internal hardware trigger is generated, which may be used to initiate an action.

The special event trigger output of CCP1 resets the TMR1 register pair. This allows the CCPR1 register to effectively be a 16-bit programmable period register for Timer1.

The special event trigger output of CCP2 resets the TMR1 register pair and starts an A/D conversion (if the A/D module is enabled).

> **Note:** The special event trigger from the CCP1and CCP2 modules will not set interrupt flag bit TMR1IF (PIR1<0>).

TABLE 12-2: CAPACITOR SELECTION FOR CRYSTAL OSCILLATOR

Osc Type	Crystal Freq.	Cap. Range C1	Cap. Range C2
LP	32 kHz	33 pF	33 pF
	200 kHz	15 pF	15 pF
XT	200 kHz	47-68 pF	47-68 pF
	1 MHz	15 pF	15 pF
	4 MHz	15 pF	15 pF
HS	4 MHz	15 pF	15 pF
	8 MHz	15-33 pF	15-33 pF
	20 MHz	15-33 pF	15-33 pF
These values are for design guidance only. See notes following this table.			
Crystals Used			
32 kHz	Epson C-001R32.768K-A	± 20 PPM	
200 kHz	STD XTL 200.000KHz	± 20 PPM	
1 MHz	ECS ECS-10-13-1	± 50 PPM	
4 MHz	ECS ECS-40-20-1	± 50 PPM	
8 MHz	EPSON CA-301 8.000M-C	± 30 PPM	
20 MHz	EPSON CA-301 20.000M-C	± 30 PPM	

Note 1: Higher capacitance increases the stability of oscillator, but also increases the start-up time.

2: Since each resonator/crystal has its own characteristics, the user should consult the resonator/crystal manufacturer for appropriate values of external components.

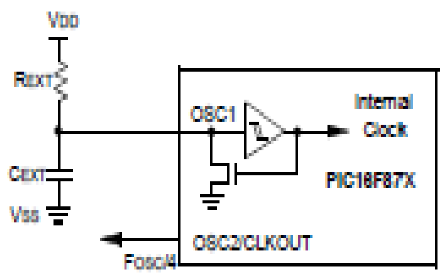
3: R_s may be required in HS mode, as well as XT mode, to avoid overdriving crystals with low drive level specification.

4: When migrating from other PICmicro devices, oscillator performance should be verified.

12.2.3 RC OSCILLATOR

For timing insensitive applications, the "RC" device option offers additional cost savings. The RC oscillator frequency is a function of the supply voltage, the resistor (REXT) and capacitor (CEXT) values, and the operating temperature. In addition to this, the oscillator frequency will vary from unit to unit due to normal process parameter variation. Furthermore, the difference in lead frame capacitance between package types will also affect the oscillation frequency, especially for low CEXT values. The user also needs to take into account variation due to tolerance of external R and C components used. Figure 12-3 shows how the R/C combination is connected to the PIC16F87X.

FIGURE 12-3: RC OSCILLATOR MODE



Recommended values: 3 kΩ ≤ REXT ≤ 100 kΩ
CEXT > 20pF

APPENDIX C

ICM 7556 CMOS Dual Timer Datasheet

19-0481; Rev 2; 11/92

MAXIM General Purpose Timers

ICM7555/7556

General Description

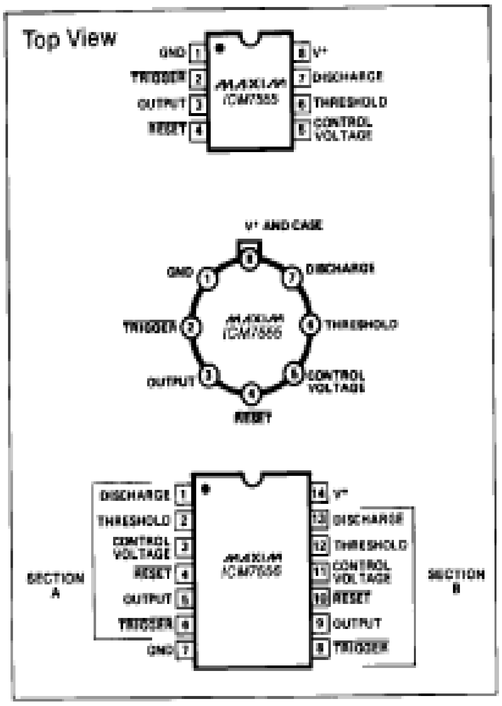
The Maxim ICM7555 and ICM7556 are respectively single and dual general purpose RC timers capable of generating accurate time delays or frequencies. The primary feature is an extremely low supply current, making this device ideal for battery-powered systems. Additional features include low THRESHOLD, $\overline{\text{TRIGGER}}$, and $\overline{\text{RESET}}$ currents, a wide operating supply voltage range, and improved performance at high frequencies.

These CMOS low-power devices offer significant performance advantages over the standard 555 and 556 bipolar timers. Low-power consumption, combined with the virtually non-existent current spike during output transitions, make these timers the optimal solution in many applications.

Applications

- Pulse Generator
- Precision Timing
- Time Delay Generation
- Pulse Width Modulation
- Pulse Position Modulation
- Sequential Timing
- Missing Pulse Detector

Pin Configuration



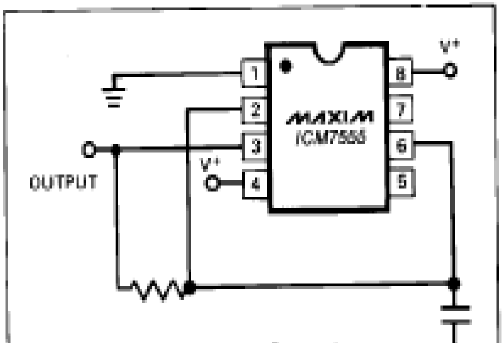
Features

- ♦ Improved 2nd Source! (See 3rd page for "Maxim Advantage™").
- ♦ Wide Supply Voltage Range: 2-18V
- ♦ No Crowbarring of Supply During Output Transition
- ♦ Adjustable Duty Cycle
- ♦ Low THRESHOLD, TRIGGER and RESET Curents
- ♦ TTL Compatible
- ♦ Monolithic, Low Power CMOS Design

Ordering Information

PART	TEMP. RANGE	PACKAGE
ICM7555IPA	-20°C to +85°C	8 Lead Plastic DIP
ICM7555IJA	-20°C to +85°C	8 Lead CERDIP
ICM7555ITV	-20°C to +85°C	TO-99 Can
ICM7555MJA	-55°C to +125°C	8 Lead CERDIP
ICM7555MTV	-55°C to +125°C	TO-99 Can
ICM7555ISA	-20°C to +85°C	8 Lead Small Outline
ICM7555/D	0°C to +70°C	Dice
ICM7556IPD	-20°C to +85°C	14 Lead Plastic DIP
ICM7556MJD	-55°C to +125°C	14 Lead CERDIP
ICM7556ISD	-20°C to +85°C	14 Lead Small Outline
ICM7556/D	0°C to +70°C	Dice

Typical Operating Circuit



Frequency Generator

(Detailed Circuit Diagram — Figure 1a)

The "Maxim Advantage™" signifies an upgraded quality level. At no additional cost we offer a second-source device that is subject to the following: guaranteed performance over temperature along with tighter test specifications on many key parameters; and device enhancements, when needed, that result in improved performance without changing the functionality.

General Purpose Timers

ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage .... +18 Volts
Input Voltage TRIGGER
Control Voltage THRESHOLD <V$^+$ + 0.3V to ≥ − 0.3V
RESET
Output Current 100mA
Power Dissipation[2] ICM7556 .... 300mW
ICM7555 .... 200mW
Operating Temperature Range
ICM7555IJA (Maxim) .... −20°C to +85°C
ICM7556ISA (Maxim) .... −20°C to +85°C
ICM7556IPA .... −20°C to +85°C
ICM7555ITV .... −20°C to +85°C
ICM7556IPD .... −20°C to +85°C
ICM7555MTV .... −55°C to +125°C
ICM7556MJD .... −55°C to +125°C
Storage Temperature .... −65°C to +150°C
Lead Temperature (Soldering 60 Seconds) .... +300°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V^+ = +2 to +15 volts; T_A = 25°C, Unless Noted)

PARAMETER	SYMBOL	TEST CONDITIONS			VALUE MIN	TYP	MAX	UNITS
Supply Voltage	V^+	$-20°C \le T_A \le +70°C$			2		18	V
		$-55°C \le T_A \le +125°C$			3		16	V
Supply Current[3]	I^+	ICM7555	V^+ = 2V			60	200	µA
			V^+ = 18V			120	300	µA
		ICM7556	V^+ = 2V			120	400	µA
			V^+ = 18V			240	600	µA
Timing Error		R_A, R_B = 1k to 100k, C = 0.1µF	$5V \le V^+ \le 15V$					
Initial Accuracy		Note 4				2.0	5.0	%
Drift with Temperature		Note 4	V^+ = 5V			50		ppm/°C
			V^+ = 10V			75		
			V^+ = 15V			100		
Drift with Supply Voltage		V^+ = 5V				1.0	3.0	%/V
Threshold Voltage	V_{TH}		V^+ = 5V		0.63	0.66	0.67	V^+
Trigger Voltage	V_{TRIG}		V^+ = 5V		0.29	0.33	0.34	V^+
Trigger Current	I_{TRIG}	V^+ = 18V				50		pA
		V^+ = 5V				10		pA
		V^+ = 2V				1		pA
Threshold Current	I_{TH}	V^+ = 18V				50		pA
		V^+ = 5V				10		pA
		V^+ = 2V				1		pA
Reset Current	I_{RST}	V_{RESET} = Ground	V^+ = 18V			100		pA
			V^+ = 5V			20		pA
			V^+ = 2V			2		pA
Reset Voltage	V_{RST}	V^+ = 18V			0.4	0.7	1.0	V
		V^+ = 2V			0.4	0.7	1.0	V
Control Voltage Lead	V_{CV}		V^+ = 5V		0.62	0.66	0.67	V^+
Output Voltage Drop	V_O	Output Lo	V^+ = 18V	I_{SINK} = 3.2mA		0.1	0.4	V
			V^+ = 5V	I_{SINK} = 3.2mA		0.15	0.4	V
		Output Hi	V^+ = 18V	I_{SOURCE} = 1.0mA	17.25	17.8		V
			V^+ = 5V	I_{SOURCE} = 1.0mA	4.0	4.5		V
Rise Time of Output	t_r	R_L = 10MΩ	C_L = 10pF	V^+ = 5V	35	40	75	ns
Fall Time of Output	t_f	R_L = 10MΩ	C_L = 10pF	V^+ = 5V	35	40	75	ns
Guaranteed Max Osc Freq	f_{max}	Astable Operation			*500			kHz

Note 1: Due to the SCR structure inherent in the CMOS process used to fabricate these devices, connecting any terminal to a voltage greater than V^+ +0.3V or less than V^- −0.3V may cause destructive latchup. For this reason it is recommended that no inputs from external sources not operating from the same power supply be applied to the device before its power supply is established. In multiple systems, the supply of the ICM7555/6 must be turned on first.

Note 2: Junction temperatures should not exceed 135°C and the power dissipation must be limited to 20mW at 125°C. Below 125°C power dissipation may be increased to 300mW at 25°C. Derating factor is approximately 3mW/°C (7556) or 2mW/°C (7555).

Note 3: The supply current value is essentially independent of the TRIGGER, THRESHOLD and RESET voltages.

Note 4: Parameter is not 100% tested. Majority of all units meet this specification.

The electrical characteristics above are a reproduction of a portion of Intersil's copyrighted (1983/1984) data book. This information does not constitute any representation by Maxim that Intersil's products will perform in accordance with these specifications. The "Electrical Characteristics Table" along with the descriptive excerpts from the original manufacturer's data sheet have been included in this data sheet solely for comparative purposes.

ICM7555/7556

MAXIM
ADVANTAGE™
General Purpose Timers

ICM7555/7556

- Lower Supply Current
- Increased Output Source Current
- Guaranteed THRESHOLD, $\overline{TRIGGER}$ and $\overline{RESET}$ Input Currents
- Guaranteed Discharge Output Voltage
- Supply Current Guaranteed Over Temperature
- Significantly Improved ESD Protection (Note 6)
- Maxim Quality and Reliability

ABSOLUTE MAXIMUM RATINGS This device conforms to the Absolute Maximum Ratings on adjacent page.

ELECTRICAL CHARACTERISTICS Specifications below satisfy or exceed all "tested" parameters on adjacent page.
(V^+ = +2 to +15 volts; T_A = 25°C, unless noted.)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	V^+	$-20°C \le T_A \le +85°C$	2		16.5	V
		$-55°C \le T_A \le +125°C$	3		16	V
Supply Current (Note 3)	I^+	**ICM 7555** V^+ = 2-16.5V; T_A = +25°C		30	250	μA
		V^+ = 5V; T_A = +25°C			120	μA
		V^+ = 5V; $-20°C \le T_A \le +85°C$			250	μA
		V^+ = 5V; $-55°C \le T_A \le +125°C$			300	μA
		ICM 7556 V^+ = 2-16.5V; T_A = +25°C		60	500	μA
		V^+ = 5V; T_A = +25°C			240	μA
		V^+ = 5V; $-20°C \le T_A \le +85°C$			500	μA
		V^+ = 5V; $-55°C \le T_A \le +125°C$			600	μA
Timing Error (Note 4)		Circuit of figure 1(b): $R_A = R_B$ = 100kΩ, C = 0.1μF, V^+ = 5V				
Initial Accuracy (Note 5)				2.0	5.0	%
Drift with Temperature		V^+ = 5V		50		ppm/°C
		V^+ = 10V		75		ppm/°C
		V^+ = 15V		100		ppm/°C
Drift with Supply Voltage		V^+ = 5V		1.0	3.0	%/V
Threshold Voltage	V_{TH}	V^+ = 5V	0.63	0.66	0.67	V^+
Trigger Voltage	V_{TRIG}	V^+ = 5V	0.29	0.33	0.34	V^+
Trigger Current	I_{TRIG}	V^+ = 16.5V		50		pA
		V^+ = 5V		10		pA
		V^+ = 2V		1		pA
Threshold Current	I_{TH}	V^+ = 16.5V		50		pA
		V^+ = 5V		10		pA
		V^+ = 2V		1		pA
Reset Current	I_{RST}	V_{RESET} = Ground V^+ = 16.5V		100		pA
		V^+ = 5V		20		pA
		V^+ = 2V		2		pA
Reset Voltage	V_{RST}	V^+ = 16.5V	0.4	0.7	1.2	V
		V^+ = 2V	0.4	0.7	1.2	V
Control Voltage	V_{CV}	V^+ = 5V	0.62	0.66	0.67	V^+
Output Voltage Drop	V_O	Output Lo V^+ = 16.5V I_{SINK} = 3.2mA		0.1	0.4	V
		V^+ = 5V I_{SINK} = 3.2mA		0.15	0.4	V
		Output Hi V^+ = 16.5V I_{SOURCE} = 2.0mA	15.75	16.25		V
		V^+ = 5V I_{SOURCE} = 2.0mA	4.0	4.5		V
Discharge Output Voltage	V_{DIS}	V^+ = 5V, I_{DIS} = 3.2mA		0.1	0.4	V
Rise Time of Output (Note 4)	t_r	R_L = 10MΩ C_L = 10pF V^+ = 5V	35	40	75	ns
Fall Time of Output (Note 4)	t_f	R_L = 10MΩ C_L = 10pF V^+ = 5V	35	40	75	ns
Guaranteed Max Osc. Freq. (Note 4)	f_{max}	Astable Operation	500			kHz

Note 1: Due to the SCR structure inherent in the CMOS process used to fabricate these devices, connecting any terminal to a voltage greater than V^+ +0.3V or less than V^- −0.3V may cause destructive latchup. For this reason it is recommended that no inputs from external sources not operating from the same power supply be applied to the device before its power supply is established. In multiple systems, the supply of the ICM7555/6 must be turned on first.

Note 2: Junction temperatures should not exceed 135°C and the power dissipation must be limited to 20mW at 125°C. Below 125°C power dissipation may be increased to 300mW at 25°C. Derating factor is approximately 3mW/°C (7556) or 2mW/°C (7555).

Note 3: The supply current value is essentially independent of the $\overline{TRIGGER}$, THRESHOLD AND $\overline{RESET}$ voltages.

Note 4: Parameter is not 100% tested. Majority of all units meet this specification.

Note 5: Deviation from $f = 1.46/(R_A + 2R_B)C$, V^+ = 5V

Note 6: All pins are designed to withstand electrostatic discharge (ESD) levels in excess of 2000V. (Mil Std 883B, Method 3015.1 Test Circuit.)

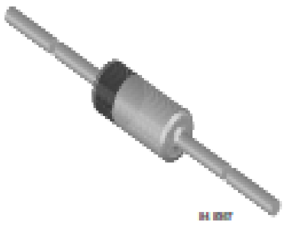
APPENDIX D

1N4148 Diode Datasheet

1N4148.1N4448

Vishay Semiconductors

Fast Switching Diodes



Features

- Silicon Epitaxial Planar Diodes
- Electrically equivalent diodes: 1N4148 - 1N914 1N4448 - 1N914B

Applications

Extreme fast switches

Mechanical Data

Case: DO-35 Glass Case

Weight: approx. 125 mg

Packaging Codes/Options:

TR / 10 k per 13 " reel (52 mm tape), 50 k/box

TAP / 10 k per Ammopack (52 mm tape), 50 k/box

Parts Table

Part	Type differentiation	Ordering code	Remarks
1N4148	V_{RRM} = 100 V, V_F @ I_F 10 mA = 1 V	1N4148-TAP or 1N4148-TR	Ammopack / Tape and Reel
1N4448	V_{RRM} = 100 V, V_F @ I_F 100 mA = 1 V	1N4448-TAP or 1N4448-TR	Ammopack / Tape and Reel

Absolute Maximum Ratings

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Value	Unit
Repetitive peak reverse voltage		V_{RRM}	100	V
Reverse voltage		V_R	75	V
Peak forward surge current	t_p = 1 µs	I_{FSM}	2	A
Repetitive peak forward current		I_{FRM}	500	mA
Forward current		I_F	300	mA
Average forward current	V_R = 0	I_{FAV}	150	mA
Power dissipation	l = 4 mm, T_L = 45 °C	P_V	440	mW
	l = 4 mm, $T_L \le$ 25 °C	P_V	500	mW

Thermal Characteristics

T_{amb} = 25 °C, unless otherwise specified

Parameter	Test condition	Symbol	Value	Unit
Junction ambient	l = 4 mm, T_L = constant	R_{thJA}	350	K/W
Junction temperature		T_j	200	°C
Storage temperature range		T_{stg}	- 65 to + 200	°C

APPENDIX E

7805 Voltage Regulator Datasheet

FAIRCHILD SEMICONDUCTOR®

www.fairchildsemi.com

KA78XX/KA78XXA

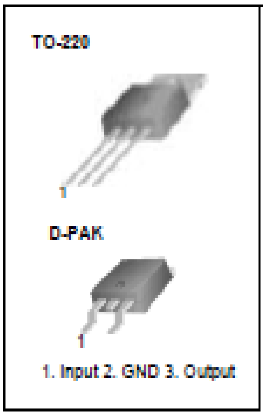
3-Terminal 1A Positive Voltage Regulator

Features

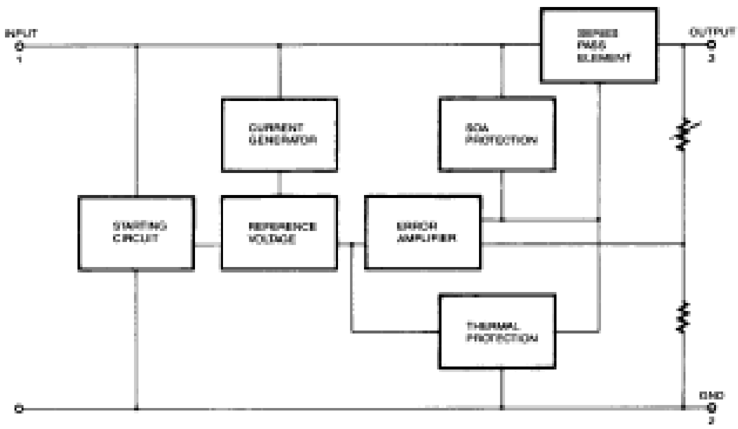
- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

Description

The KA78XX/KA78XXA series of three-terminal positive regulator are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.



Internal Block Digram



Rev. 1.0.0

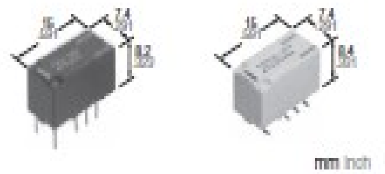
APPENDIX F

Relay TX Series Datasheet

Panasonic
ideas for life

2 A CAPACITY RELAY WITH HIGH SURGE VOLTAGE & HIGH BREAKDOWN VOLTAGE

TX RELAYS



RoHS Directive compatibility information
http://www.nais-e.com/

FEATURES

- Breakdown voltage between contacts and coil: 2,000 V
- Surge withstand between contacts and coil: 2,500 V
- High contact capacity: 2 A 30 V DC
- Surface-mount type available

7.5A Maximum Switching Current Now Available

SPECIFICATIONS

Contact

Arrangement			2 Form C
Initial contact resistance, max. (By voltage drop 6 V DC 1 A)			100 mΩ
Contact material			Standard contact: Ag+Au clad, AgPd contact (low level load): AgPd+Au clad (stationary), AgPd (movable)
Rating	Nominal switching capacity (resistive load)		2 A 30 V DC
	Max. switching power (resistive load)		60 W
	Max. switching voltage		220 V DC
	Max. switching current		2 A
	Min. switching capacity (Reference value)#1		10 μA 10 mV DC
Nominal operating power	Single side stable		140 mW (1.5 to 24 V DC) 270 mW (48 V DC)
	1 coil latching		100 mW (1.5 to 24 V DC)
	2 coil latching		200 mW (1.5 to 24 V DC)
Expected life (min. operations)	Mechanical (at 180 cpm)		10^8
	Electrical (at 20 cpm)	2 A 30 V DC resistive	10^5
		1 A 30 V DC resistive	5×10^5

Notes:
#1 This value can change due to the switching frequency, environmental conditions, and desired reliability level, therefore it is recommended to check this with the actual load. (AgPd contact type or SX relays are available for low level load switching [10V DC, 10mA max. level])
#2 The upper limit for the ambient temperature is the maximum temperature that can satisfy the coil temperature rise. Under the packing condition, allowable temperature range is from –40 to +70°C –40° to +158°F.

Remarks
* Specifications will vary with foreign standards certification ratings.
*1 Measurement at same location as "Initial breakdown voltage" section.
*2 By resistive method, nominal voltage applied to the coil; contact carrying current: 2 A.
*3 Nominal voltage applied to the coil, excluding contact bounce time.
*4 Nominal voltage applied to the coil, excluding contact bounce time without diode.
*5 Half-wave pulse of sine wave: 6 ms; detection time: 10 μs.
*6 Half-wave pulse of sine wave: 6 ms.
*7 Detection time: 10 μs.
*8 Refer to 6. Conditions for operation, transport and storage mentioned in AMBIENT ENVIRONMENT

Characteristics

Initial insulation resistance*1		Min. 1,000 MΩ (at 500 V DC)
Initial breakdown voltage	Between open contacts	1,000 Vrms for 1 min. (Detection current: 10 mA)
	Between contact sets	1,000 Vrms for 1 min. (Detection current: 10 mA)
	Between contact and coil	2,000 Vrms for 1 min. (Detection current: 10 mA)
Initial surge voltage	Between open contacts (10×160 μs)	1,500 V (FCC Part 68)
	Between contacts and coil (2×10 μs)	2,500 V (Telcordia)
Temperature rise*2 (at 20°C)		Max. 50°C
Operate time [Set time]*3 (at 20°C)		Max. 4 ms [Max. 4 ms]
Release time [Reset time]*4 (at 20°C)		Max. 4 ms [Max. 4 ms]
Shock resistance	Functional*5	Min. 750 m/s² (75 G)
	Destructive*6	Min. 1,000 m/s² (100 G)
Vibration resistance	Functional*7	196 m/s² (20 G), 10 to 55 Hz at double amplitude of 3.3 mm
	Destructive	294 m/s² (30G), 10 to 55 Hz at double amplitude of 5 mm
Conditions for operation, transport and storage*8 (Not freezing and condensing at low temperature)	Ambient temperature#2	–40°C to +85°C (up to 24 V coil) –40°F to +185°F (up to 24 V coil) –40°C to +70°C (48 V coil) –40°F to +158°F (48 V coil)
	Humidity	5 to 85% R.H.
Unit weight		Approx. 2 g .071 oz

TX2SA-LT-*V-TH
- 7.5A inrush current rating
- 2.4V coil voltage option
- Industry standard footprint

See Note 3 under ordering information for part number selection

APPENDIX G

2N3819 N-channel JFET Datasheet

Philips Components

Data sheet	
status	Preliminary specification
date of issue	October 1990

2N3819
N-channel J-FET

FEATURES

- Low cost
- Specified at 100 MHz
- Automatic insertion package.

DESCRIPTION

N-channel junction field-effect transistor in a plastic TO-92 envelope. It is intended for use in general purpose amplifiers and for analog switching.

PINNING - TO-92

PIN	DESCRIPTION
1	drain
2	gate
3	source

PIN CONFIGURATION

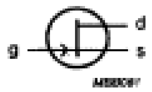


Fig.1 Symbol.

LIMITING VALUES

In accordance with the Absolute Maximum System (IEC 134)

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
$\pm V_{DS}$	drain-source voltage		-	25	V
$-V_{GSO}$	gate-source voltage	open drain $I_D = 0$	-	25	V
V_{DGO}	drain-gate voltage	open source $I_S = 0$	-	25	V
I_G	gate current		-	10	mA
P_{tot}	total power dissipation	$T_{amb} = 25$ °C	-	360	mW
T_{stg}	storage temperature range		−65	150	°C
T_j	junction temperature		-	150	°C

THERMAL RESISTANCE

SYMBOL	PARAMETER	VALUE	UNIT
$R_{th\ j\text{-}a}$	from junction to ambient	347	K/W

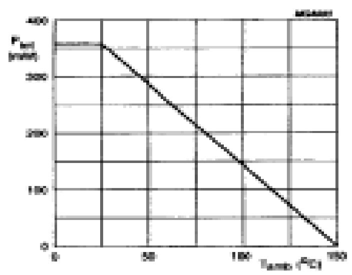


Fig.2 Total power dissipation as a function of ambient temperature.

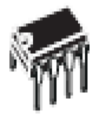
APPENDIX H

TL071 JFET Datasheet

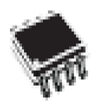
TL071
TL071A - TL071B

LOW NOISE J-FET SINGLE OPERATIONAL AMPLIFIERS

- WIDE COMMON-MODE (UP TO V_{CC}^{+}) AND DIFFERENTIAL VOLTAGE RANGE
- LOW INPUT BIAS AND OFFSET CURRENT
- LOW NOISE e_n = 15nV/√Hz (typ)
- OUTPUT SHORT-CIRCUIT PROTECTION
- HIGH INPUT IMPEDANCE J–FET INPUT STAGE
- LOW HARMONIC DISTORTION : 0.01% (typ)
- INTERNAL FREQUENCY COMPENSATION
- LATCH UP FREE OPERATION
- HIGH SLEW RATE : 16V/µs (typ)



N
DIP8
(Plastic Package)



D
SO8
(Plastic Micropackage)

DESCRIPTION

The TL071, TL071A and TL071B are high speed J–FET input single operational amplifiers incorporating well matched, high voltage J–FET and bipolar transistors in a monolithic integrated circuit.

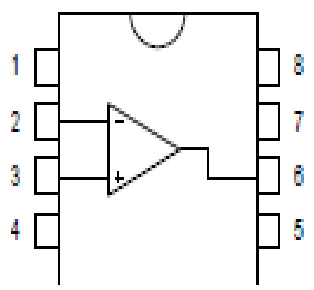
The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.

ORDER CODE

Part Number	Temperature Range	Package	
		N	D
TL071M/AM/BM	-55°C, +125°C	•	•
TL071I/AI/BI	-40°C, +105°C	•	•
TL071C/AC/BC	0°C, +70°C	•	•
Example : TL071CN			

N = Dual in Line Package (DIP)
D = Small Outline Package (SO) - also available in Tape & Reel (DT)

PIN CONNECTIONS (top view)



1 - Offset null 1
2 - Inverting input
3 - Non-inverting input
4 - V_{CC}^{-}
5 - Offset null 2
6 - Output
7 - V_{CC}^{+}
8 - N.C.

APPENDIX I

BC549 npn Transistor Datasheet

NPN general purpose transistors BC549; BC550

FEATURES

- Low current (max. 100 mA)
- Low voltage (max. 45 V).

APPLICATIONS

- Low noise stages in audio frequency equipment.

DESCRIPTION

NPN transistor in a TO-92; SOT54 plastic package.
PNP complements: BC559 and BC560.

PINNING

PIN	DESCRIPTION
1	emitter
2	base
3	collector

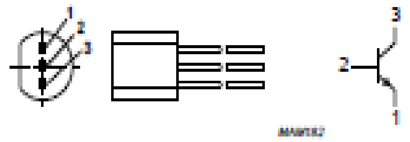


Fig.1 Simplified outline (TO-92; SOT54) and symbol.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
BC549C	SC-43A	plastic single-ended leaded (through hole) package; 3 leads	SOT54
BC550C			

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 60134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CBO}	collector-base voltage	open emitter			
	BC549		–	30	V
	BC550		–	50	V
V_{CEO}	collector-emitter voltage	open base			
	BC549		–	30	V
	BC550		–	45	V
V_{EBO}	emitter-base voltage	open collector	–	5	V
I_C	collector current (DC)		–	100	mA
I_{CM}	peak collector current		–	200	mA
I_{BM}	peak base current		–	200	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25$ °C; note 1	–	500	mW
T_{stg}	storage temperature		–65	+150	°C
T_j	junction temperature		–	150	°C
T_{amb}	ambient temperature		–65	+150	°C

Note

1. Transistor mounted on an FR4 printed-circuit board.

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	VALUE	UNIT
$R_{th(j-a)}$	thermal resistance from junction to ambient	note 1	250	K/W

Note

1. Transistor mounted on an FR4 printed-circuit board.

CHARACTERISTICS

T_{amb} = 25 °C unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I_{CBO}	collector-base cut-off current	V_{CB} = 30 V; I_E = 0 A	–	–	15	nA
		V_{CB} = 30 V; I_E = 0 A; T_j = 150 °C	–	–	5	µA
I_{EBO}	emitter-base cut-off current	V_{EB} = 5 V; I_C = 0 A	–	–	100	nA
h_{FE}	DC current gain	V_{CE} = 5 V; see Fig.2				
		I_C = 10 µA	–	270	–	
		I_C = 2 mA	420	520	800	
V_{CEsat}	collector-emitter saturation voltage	I_C = 10 mA; I_B = 0.5 mA	–	90	250	mV
		I_C = 100 mA; I_B = 5 mA	–	200	600	mV
V_{BEsat}	base-emitter saturation voltage	I_C = 10 mA; I_B = 0.5 mA; note 1	–	700	–	mV
		I_C = 100 mA; I_B = 5 mA; note 1	–	900	–	mV
V_{BE}	base-emitter voltage	V_{CE} = 5 V; I_C = 2 mA; note 2	580	660	700	mV
		V_{CE} = 5 V; I_C = 10 mA; note 2	–	–	770	mV
C_c	collector capacitance	V_{CB} = 10 V; I_E = I_e = 0 A; f = 1 MHz	–	1.5	–	pF
C_e	emitter capacitance	V_{EB} = 0.5 V; I_C = I_c = 0 A; f = 1 MHz	–	11	–	pF
f_T	transition frequency	V_{CE} = 5 V; I_C = 10 mA; f = 100 MHz	100	–	–	MHz
F	noise figure	V_{CE} = 5 V; I_C = 200 µA; R_S = 2 kΩ; f = 10 Hz to 15.7 kHz	–	–	4	dB
		V_{CE} = 5 V; I_C = 200 µA; R_S = 2 kΩ; f = 1 kHz; B = 200 Hz	–	–	4	dB

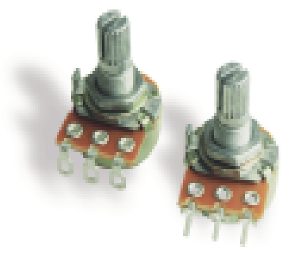
Notes

1. V_{BEsat} decreases by about 1.7 mV/K with increasing temperature.
2. V_{BE} decreases by about 2 mV/K with increasing temperature.

APPENDIX J

Potentiometer Datasheet

Model P160
16mm Rotary Potentiometer
Conductive Plastic Element
100,000 Cycle Life
Metal shaft / Bushing
Multi – Ganged available
RoHS Compliant



MODEL STYLES	
Side Adjust , Solder Lugs	P160KNP
Side Adjust , PC pins	P160KN
Side Adjust , PC Pins, Long pins	P160KN2
Rear Adjust, PC pins	P160KNPD

ELECTRICAL[1]	
Resistance Range, Ohms	500-1M
Standard Resistance Tolerance	± 20%
Residual Resistance	20 ohms max.
Power rating Input Voltage, maximum	200 Vac max.
Power Rated, Watts	0.2W- B taper, 0.1W-others
Dielectric Strength	500Vac, I minute
Insulation Resistance, Minimum	100M ohms at 250Vdc
Sliding Noise	100mV max.
Actual Electrical Travel, Nominal	260°

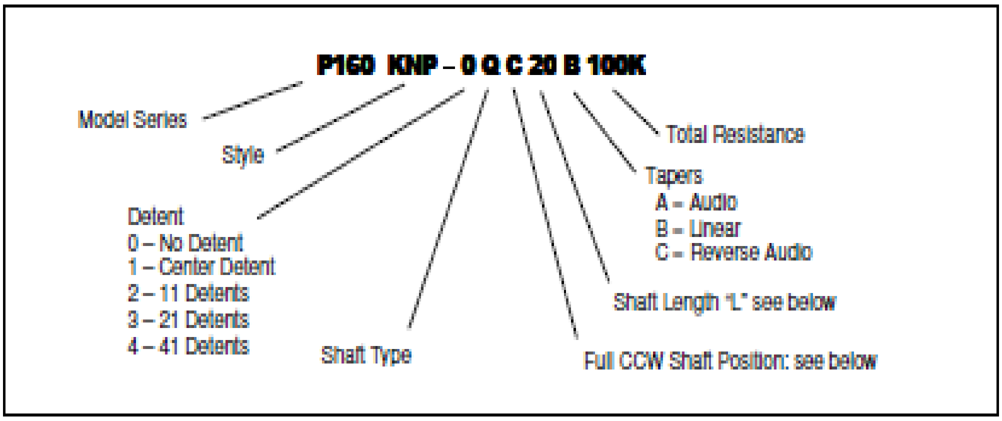
MECHANICAL	
Total Mechanical Travel	300°± 10°
Static Stop Strength	90 oz-in
Rotational Torque, Maximum	2.5 oz-in

ENVIRONMENTAL	
Operating Temperature Range	-20°C to +70°C
Rotational Life	100,000 cycles

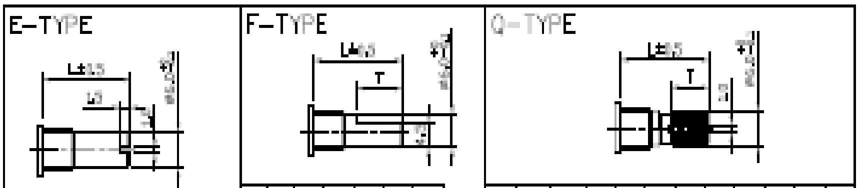
[1] *Specifications subject to change without notice.*

Model P160

ORDERING INFORMATION[2]



Shaft Types



E-TYPE

L	10	15	20	25	30	35	40

F-TYPE

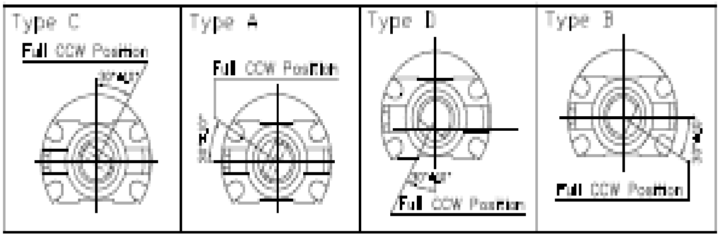
L	15	18	20	25	30	35
T	7	10	12	12	12	12

Q-TYPE

L	10	12	13	14	15	17	20	25	30	35	45
T	2.5	4.5	4	5	6	8	10	12	12	12	12

Shaft Position (F-Type Shaft)

Dashed lines on Type "C" and Type "A" shows position of adjustment slot for E-Type and Q-Type shafts



STANDARD RESISTANCE VALUES, OHMS

500	1K	2K	5K	10K	20K	50K	100K	200K	500K	1MEG

CIRCUIT DIAGRAM