TYRE PRESSURE MONITORING SYSTEM
(CONTROLLER AND DISPLAY)

By

FARAH HANNAN BT AZIZAN

FINAL PROJECT REPORT

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

Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved:

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Ms Illani M Nawi
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

December 2006

CERTIFICATION OF ORIGINALITY

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

FARAH HANNAN BT AZIZAN

ABSTRACT

Maintaining the correct tyre pressure for a vehicle is the variable on how much load its tyres can safely drive. The correct tyre pressure can carry the weight without a problem. Too little tyre pressure will eventually cause tyre failure that can lead to many unpleasant accidents. This project requires students to study the existing system of TPMS and to come up with depth research on how to design the system from scratch and prepare the model of this system. This project is the initial background work for the development of the miniature pressure sensor and controller unit for TPMS. This main purpose of these systems is to warn the driver if their tyres are loosing air pressure, leaving the tyres under inflated and dangerous. The systems attach a pressure sensor together with transmitter to the vehicle's wheel inside the tyre's air chamber. This project is performed by two students, the author and Mr Khairul Asyraff. Mr Khairul Asyraff did the sensor and transmitter part while the author did the microcontroller and the display part and finally both parts are being merged and integrated. The final objective of the project is to design circuit consist of pressure sensor, microcontroller (PIC), transmitter and receiver. The pressure sensor used is a microelectronic device. This system will read a pressure inside a tyre and transmit it to the receiver which can produce the output (display). This report represents approaches to the scope of developing microcontroller and LCD display to warn the driver that the tyre pressure is not sufficient. Input from pressure sensor is required before a transmitter transmits data to receiver and the signal will be transmit to microcontroller to convert the signal from analogue to digital before the value being display. Mostly the related information is collected from reference books and from the internet. As for conclusion, tyre pressure monitoring system is an interesting area and important to make sure the safety of the driver and everyone inside the car.

ACKNOWLEDGEMENTS

First the author would like to take this opportunity to express his sincere gratitude to all parties involved in making my Electrical and Electronic Final Year Project success. The author's deepest appreciation goes to project supervisor, Ms Illani M Nawi for her support, guidance, patient and also, for her brilliant ideas in solving problems that the author faced throughout the design process. Special thanks also for author's teammate, Mr Khairul Ashraf for making this project succeed.

The author also would like to record the special thanks to Ms Nasreen, Ms Norashikin and Ms Salina, the coordinator of Final Year Project. Without their management and coordination, the flow of this project might not be as expected.

Special thanks also for Ms Siti Hawa who has given the author numerous technical supports as lab technician. She has been helpful to prepare the electronics components and parts of the project. Very special thanks to Mr Taib Ziad ,and Mr Abu Bakar Sayuti, who have thought and gave advices to the author in many areas which was not known to the author before. Their help in giving ideas and programming skills is also one of the key factors of success of this project.

I wish to thank my very special one, Khairul Zakwan Chung Bin Abdullah, my housemates, and my course mates who have shown their concern and willingness to help for the success of my project from the beginning until the end. From the bottom of my heart, I would like to thank them for their prayers, word of wisdom, encouragement and support.

Lastly, I really feel grateful and thankful to my parents and my siblings for their moral support to me in completing this project successfully.

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LIST OF ABBREVIATIONS

1. TPMS- Tyre Pressure Monitoring System
2. LCD- Liquid Crystal Display
3. RKE-remote keyless entry
4. ASIC- integrated on single chips
5. ADC- Analogue to Digital Converter
6. OTP- One Time Programmable
7. I/O-Input/ Output
8. PC- Program Counter
9. PCL- Program Counter Low byte
10. PCB - Printed Circuit Board
11. LED- Light Emitting Diode
12. RF- Radio Frequency
13. IR- Infra Red

CHAPTER 1
INTRODUCTION

1.1 Background of study

Generally it's difficult to spot under inflated tyres with the human eye, they may become dangerously under inflated before you even realize! Whatever transport you ride, for safety's sake we all have to take care of our tyres.

A direct tyre pressure monitoring system will required a very long battery life, 7 to 10 years. The battery will recite inside the tyre so a heavy, bulky battery is not suitable. The frequency of measurement and transmission also must be carefully considered. In addition, low power consumption components must be chosen.

Most auto manufacturer will require 7 to 10 year operational lifetime for a TPM module. To meet this requirement, each component must have a very low current standby or idle mode, as well as efficient measurement and transmission hardware.

Inside the tyre is a very harsh environment, with possible temperatures from -40 to +125 C and exposure to moisture, tyre mounting grease, and a variety of other potentially corrosive material. Careful package design is necessary to allow a broad temperature range and robust media compatibility. As with practically all automotive applications, cost is a major issue. Integrating the functionality of the TPMS and the remote keyless entry (RKE) receiver can help to reduce the overall system cost. Also, smaller, more highly integrated components to reduce board space can present significant saving.[6]

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1.2 Problem Statement

It is important to maintain the correct tyre pressure to make sure that our journey is safe and we can prevent dangerous situation from happen. So the aim of this project is to do research to produce the system that can monitor the pressure inside the car. Most of the car owner nowadays irregularly checks the pressure inside the tyre even though it is very important. So Tyre Pressure Monitoring System (TPMS) is a very suitable method to monitor the pressure inside the tyre so that it is in desired range[6]. Tyre Pressure Monitoring System (TPMS) will warn the driver that the tyre is under inflated which could decrease the performance of the vehicle and increases the risk of crashing. Inflated tyres are difficult to spot visually, especially without a fully inflated tyre as a comparison [7]. The tyre will only show a slight slump when the pressure inside is not in the correct range. Meaning that we can't determine whether the pressures are suitable by just looking at the tyre visually. This is why Tyre Pressure Monitoring System (TPMS) can be useful as it can warn driver that their tyre is under inflated condition even though the tyre looking normal [7]. There are many dangers to have under inflated tyres because they are designed for use at recommended pressure. The consequences to have inflated tyres are:

- Reduces handling characteristics and reduced control of the vehicle[7]
- Longer stopping distances[7]
- Higher chances of the tyre delaminating especially in the wet, which could lead to a sudden tyre failure[7]
- Deformation in tyre wall, which reduces the amount of surface contact the tyre with the road[7]
- Fuel economy will be reduced by as much as 10% [6]
- Braking performance will be reduced by around 20%![6]
- Putting you and your passengers at unnecessary RISK[6]
- Tyres can be under inflated by as much as 50% before it's noticed![6]
- Increased wear of the tyres treads which will lead to a higher chance of aquaplaning in the wet

1.3 Objectives

There are general and specific objective and scope of the project. The general objectives of the projects are:

- Create on existing tyre pressure monitoring systems to get brief knowledge on how the system work
- Continue doing research and develop a model to represent this system.
- Produce step by step approach, starting with the transmitter and receiver part and followed with microcontroller and display part.
- To design a system that can be commercialized in automotive industrial.

The specifics objectives of the projects are:

- Find program to control transmitter and receiver using PIC 16F877. Use supposed input from sensor and process it using the chosen microcontroller.
- Testing and simulation of controlling transmitter and receiving by PIC controller
- Find program to receive input and display desired output .
- Display panel testing and simulation by PIC controller, initiation of input signal into the controller and produced desired output

This project was relevant because it can prevent car owner from having accidents just because of the inflated tyres. This is because we can't determine whether the tyre have the sufficient amount of pressure just by looking at the tyre. So by introducing this system, it can help to make sure that the tyres have the sufficient amount of pressure

CHAPTER 2
LITERATURE REVIEW

Tyre pressure monitoring becomes very important on automotive industries market. The transmitter will be placed inside the tyres while the receiver is being placed inside the car for safety reason. There are few evaluation had been made based on the research. One method is by using Pressure Sensor Based System. By using this method, the pressure sensor will be mounted on each tyre. The sensor will communicate with the receiver. Each sensor will have different digital identification code so that tyre with low pressure could be identified on the drivers display. Different digital identification code is to prevent signals from other vehicles sensor from being analyzed by the TPMS. Below is one example of my finding regarding this topic.

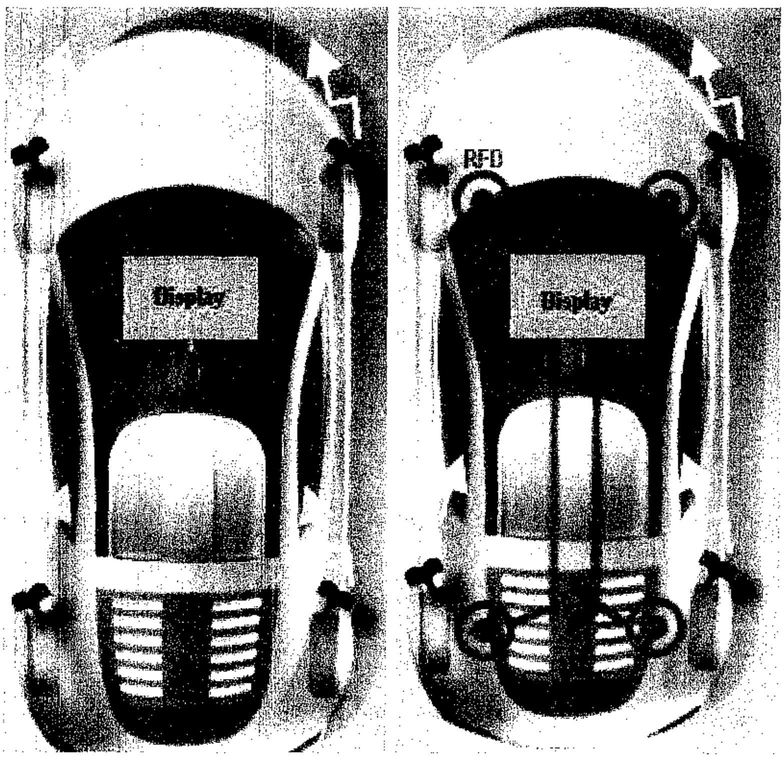
2.1 ORANGE TPMS

Orange has two solutions for OEM markets; standard function and advanced function (option).

The TPMS contains a component for electric power supply. The main components of an active battery operated tire pressure monitoring system are battery, processor, memory, sensors, radio component and antenna. These components are integrated on single chips (ASIC) to save weight and space and to reduce power consumption. The sensors typically measure pressure and temperature. Orange also use a simple acceleration sensor or a switch that helps determine whether the tire is rotating or not. The most important of components of TPM System, which are the transmitters. This device transmit the accurate data to receiver, and inform the driver these tires' pressure and temperature. Thus, the sensor of pressure and temperature, antenna's transmitting distance, frequency, and the battery's life, and the weight of transmitter become the key function for these transmitting.

This is an original equipment system, in other words, installed during the car manufacturing, the receiver is typically integrated into the car and connected with an external display and keyboard, e.g. the control panel of the car. Sometimes the receiver can be more or less integrated in the remote keyless entry system of the car. In some OE-products the receiver uses several antennas, one near each wheel. In such a case, the positions of the tire sensors under the vehicle can be automatically detected.

In Advanced solution (Option) of Orange design. It will add a trigger in each transmitter of tire. Meanwhile, the transmitter will not be wake up by Vehicle driven over 25 MPH, but when the driver switch on the ignition, the receiver will send a signal to each tire and wake up the transmitter to activity. Then the transmitter will immediately transmit the tire temperature and pressure to receiver



Basic System High End System

Figure 1 :Different for the Basic solution and Advanced solution (options)

This function like all the car system, when a driver switch on the ignition, the ECU will check all the engine parts and shown what result before vehicle move.

Table 1 can easy compare the different for the Basic solution and Advanced solution (option).

	Orange	**Other competitors**	**Differentiation**
Receiver	Embedded in display and integrate check and warning function for OEM	External display box	Experienced in OEM
Sensor	Basic and Advance solutions	Basic solution	Orange has been test by carmaker
Housing of transmitter	Has reinforced the structure for housing of transmitter	Without reinforced housing, easy broken for assemble when transmitter screw in a wheel	Has been test by carmaker, and reinforced the structure in housing of transmitter, easy for assembly in carmaker
Battery	With 8 year battery life, and the same with BMW model	Using the normal battery, cannot meet the high/low temperature, and the battery cannot maintain longer	OEM need more battery life(at least 7years), and need to qualified by high/ low temperature. Orange's battery can meet the temperature from -40 to 120 °C, and even can up to 150°C
Antenna	With strong signal and embedded design, also has patent protection	Very short antenna with shorten distance transmitter, or easy broken when vehicle vibration	• strong structure • long distance signal transmit • accurately data • increase battery life • patent protection
Strong R&D supporting	Orange has experienced R&D center and cooperate with carmakers to perform the TPM System practicability	Most competitors only doing the aftermarket, but OEM	Experienced and qualified by carmaker, and continue invest in TPM System and related research

Table 1 : Orange vs. other competitor

Moreover, in this project, the author has to do the microcontroller and the display part. The author has done much research in order to find suitable microcontroller and display method that can be applied in this project. Below are the example of the microcontroller and the display method that the author can found during research:

2.2 Microcontroller

For this project, the author must find the controller that can convert from analogue to digital. This is because the transmitter and receiver are operating in analogue mode so we must find the microcontroller to convert the signal into the digital mode because we want to display it on the display panel.

Many microcontrollers contain on-chip ADCs. Typical devices include the Microchip PIC167C7xx family and the Atmel AT90S4434. Most microcontroller ADCs are successive approximation because this gives the best tradeoff between speed and the cost of real estate on the microcontroller die.

The PIC16C7xx microcontrollers contain an 8-bit successive approximation ADC with analog input multiplexers. The microcontrollers in this family have from four to eight channels. Internal registers control which channel is selected, start of conversion, and so on. Once an input is selected, a settling time must elapse to allow the S/H capacitor to charge before the A/D conversion can start. The software must ensure that this delay takes place.

Some of the microcontrollers are:

2.2.1 8-bit A/D Microcontroller HT46R22 [12]

HT46R22 is a new generation 8-bit A/D 2K One Time Programmable (OTP) Microcontroller. While designed mainly with the high-level domestic appliance and industrial control area in mind, its embedded A/D converter and PWM D/A converter makes it an extremely valuable and flexible MCU device for designers of these products. By eliminating the need for external A/D and PWM D/A components, major savings in overall product costs can be achieved as well as simplifying the production process, increasing product reliability and reducing part inventory. During the product design and production process, the flexibility offered through the OTP capabilities of the device allows for rapid and efficient user program changes resulting in faster design to market times.

The internal PWM D/A is a 8-bit D/A and was designed to work with a high frequency carrier wave. In D/A converter applications this feature offers the advantage of reducing the size and weight of the necessary external power output inductor with resulting improvements in overall power efficiency. Using the PWM output is simplified by having the PWM registers shared with two I/O registers, both of which can be directly written to. The A/D converter is an 8-channel 9-bit resolution type which offers the user the flexibility of software controlled A/D options and channel selection. Serial communication for the HT46R22 is provided through an I2C bus allowing for extremely convenient and simplified on board application communication.

With its flexible and programmable design features, the HT46R22 is especially suited for a large range of industrial control and various electrical appliance applications such as switching power supplies, multi-function battery chargers, household appliances etc.

The HT46R22/HT46C22 are 8-bit, high performance, RISC architecture microcontroller devices specifically designed for A/D applications that interface directly to analog signals, such as those from sensors. The mask version HT46C22 is fully pin and functionally compatible with the OTP version HT46R22 device. The advantages of low power consumption, I/O flexibility, programmable frequency divider, timer functions, oscillator options, multi-channel A/D Converter, Pulse Width Modulation function, I2C interface, HALT and wake-up functions, enhance the versatility of these devices to suit a wide range of A/D application possibilities such as sensor signal processing, motor driving, industrial control, consumer products, subsystem controllers, etc.[12]

2.2.2 PIC16F877 [12]

The PIC16F877 is a microcontroller which has 8K x 14-bit words of Flash program memory, 368 bytes of data RAM, 256 bytes of data EEPROM and an 8-level x 13 bit wide hardware stack.

The Program Counter (PC) of this PIC is 13 bits wide, thus making it possible to access all 8K x 14 addresses. The low byte is the PCL (Program Counter Low byte) register which is a readable and writable register. The high byte of the PC is not directly readable or writable and comes from the PCLATH (Program Counter LATH High) register. The PCLATH register is a holding register for the PC. The contents of the PCLATH are transferred to the upper byte of the program counter when the PC is loaded with a new value. Although the PC is capable of addressing the entire program memory space, conceptually the program memory is represented by four banks of 2K the 14-bit words. Banking is necessary since there are only 11 bits for the address in the instruction word for a call or go to. The other two bits are obtained from the top two bits of PCLATH. This means that the PC must be set those extra bits in PCLATH before branching out of the 2K bank that contains the current instruction. Within the program memory space, the reset vector (location to go to on reset) is at 0000h and the interrupt vector (location to go to on interrupt) is at 0004h. The data memory space effectively has 9 bit addresses, and is also banked. There are 4 banks; each bank holds 128 bytes of addressable memory. The banked arrangement is necessary because there are only 7 bits are available in the instruction word for the addressing of a register, which gives only 128 addresses. The selection of the banks is determined by control bits RP1, RP0 in the STATUS register .Together the RP1, RP0 and the specified 7 bits effectively form a 9 bit address. The first 32 locations of Banks 1 and 2, and the first 16 locations of Banks 2 and 3 are reserved for the mapping of the Special Function Registers (SFR's). SFRs (e.g. PC, STATUS) are used to control the core operation of the microcontroller as well as peripherals such as the I/O ports. The SFRs are mapped into the data memory space to facilitate addressing.

The 368 bytes of static RAM which are used as general purpose registers (GPR) are arranged in the data memory space so that each is accessed by a unique address, with the exception of the last 16 bytes of each bank, which are shared. Each mapped SFR and GPR is 8-bits wide. The entire data memory can be accessed either directly using the absolute address of each register file, or indirectly through the INDirect File (INDF) register and the File Select Register (FSR). The INDF register is not a physical register. Any instruction using the INDF register actually accesses the register pointed to by the FSR. Reading the INDF register itself, indirectly (i.e. FSR = 0) will read 00h. Writing to the INDF register indirectly results in a no operation (although status bits may be affected). Because the FSR is 8 bits wide, indirect addressing can access two data memory banks simultaneously. The effective 9-bit address is obtained by concatenating the IRP bit and the 8-bit FSR register.

The 256 bytes (8 bit address) of EEPROM memory is indirectly mapped into the data memory using the EEPROM Address (EEADR), EEPROM Control (EECON1) and EEPROM DATA (EEDATA) registers6. Reading the data EEPROM memory only requires that the desired address to access be written to the EEADR register and the EEPGD bit of the EECON1 register be cleared (to indicate the data memory is to be read). Then, once the RD bit of the EECON1 register is set7, data will be available in the EEDATA register on the very next instruction cycle. EEDATA will hold this value until another read operation is initiated or until it is explicitly written. The stack is not part of the program or data space and the stack pointer is not readable or writable.

There are also no operations to place or remove data to or from the stack. Addresses are placed on the stack by the CPU when a call instruction is executed or when an interrupt occurs. The various return instructions then remove the previously stored address from the stack. The stack operates as a circular buffer, meaning that after the stack is full, subsequent 'pushes' start overwriting the previously stored data from the top (the very first push). Similarly when the stack is 'popped' nine times, the ninth value is the same as the first pop. The programmer never has to interact directly with the stack, but should always remember the 8-level limit. The stack does not give any indication if overflow or underflow occurs. The 8-bit working register (W) is also not part of the program or data memory space. It can however be read/written using particular instructions. Register-Register operations are not possible.[12]

2.3 Display

The other important characteristic for these project are the display. The author has to choose a suitable display panel to display the amount of pressure inside the tires. The display should be suitable in order to display the value and maybe some wordings. The author also had done some research in order to find the suitable display for the project:

2.3.1 LCD display [9]

Liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. It is prized by engineers because it uses very small amounts of electric power, and is therefore suitable for use in battery-powered electronic devices.

Each pixel (picture element) consists of a column of liquid crystal molecules. Without the liquid crystals between them, light passing through one would be blocked by the other. The liquid crystal twists the polarization of light entering one filter to allow it to pass through the other.

The molecules of the liquid crystal have electric charges on them. By applying small electrical charges to transparent electrodes over each pixel or subpixel, the molecules are twisted by electrostatic forces. This changes the twist of the light passing through the molecules, and allows varying degrees of light to pass (or not to pass) through the polarizing filters.

Before applying an electrical charge, the liquid crystal molecules are in a relaxed state. Charges on the molecules cause these molecules to align themselves in a helical structure, or twist (the "crystal"). In some LCDs, the electrode may have a chemical surface that seeds the crystal, so it crystallizes at the needed angle. Light passing through one filter is rotated as it passes through the liquid crystal, allowing it to pass through the second polarized filter. A small amount of light is absorbed by the polarizing filters, but otherwise the entire assembly is transparent.

When an electrical charge is applied to the electrodes, the molecules of the liquid crystal align themselves parallel to the electric field, thus limiting the rotation of entering light. If the liquid crystals are completely untwisted, light passing through them will be polarized perpendicular to the second filter, and thus be completely blocked. The pixel will appear unlit. By controlling the twist of the liquid crystals in each pixel, light can be allowed to pass though in varying amounts, correspondingly illuminating the pixel.

Many LCDs are driven to darkness by an alternating current, which disrupts the twisting effect, and become faint or transparent when no current is applied.

To save cost in the electronics, LCDs are often *multiplexed*. In a multiplexed display, electrodes on one side of the display are grouped and wired together, and each group gets its own voltage source. On the other side, the electrodes are also grouped, with each group getting a voltage sink. The groups are designed so each pixel has a unique, unshared combination of source and sink. The electronics, or the software driving the electronics then turns on sinks in sequence, and drives sources for the pixels of each sink.

Important factors to consider when evaluating an LCD monitor include resolution, viewable size, response time (sync rate), matrix type (passive or active), viewing angle, color support, brightness and contrast ratio, aspect ratio, and input ports (e.g. DVI or VGA) [9]

LCD technology still has a few drawbacks in comparison to some other display technologies:

- While CRTs are capable of displaying multiple video resolutions without introducing artifacts, LCD displays usually produce only crisp images in their "native resolution" or even fractions of it. [9]

- LCD displays generally have a lower contrast ratio than that on a plasma display or CRT. This is due to their "light valve" nature: some light always leaks out making black grey. [9]
- LCDs have longer response time than their plasma and CRT counterparts, creating ghosting and mixing when images rapidly change; this caveat however is continually improving as the technology progresses. [9]
- The viewing angle of a LCD is usually less than that of most other display technologies thus reducing the number of people who can conveniently view the same image. However, this negative has actually been capitalised upon in two ways. Some vendors offer portables with intentionally reduced viewing angle, to provide additional privacy for example when using the PC in airplanes. Secondly, it allows multiple TV outputs from the same LCD screen just by changing the angle from where the TV is seen. Such a set can also show two different images to one viewer, providing 3-D. [9]
- Many users of older (around pre-2000) LCD monitors get migraines and other severe eyestrain problems from the flicker nature of the fluorescent backlights. If you experience eyestrain issues with LCDs, consider these possibilities: using a small resolution for reading text, on a >=15 inch LCD, glare from another light, brightness is set too low or high, defective backlight, LCD monitor is too close, or too far away, Not using WindowsXP Cleartype (generally helps improve font visibility, but can cause some problems in some cases). [9]

LCD screens occasionally suffer from image persistence, which is similar to screen burn on CRT displays[9]

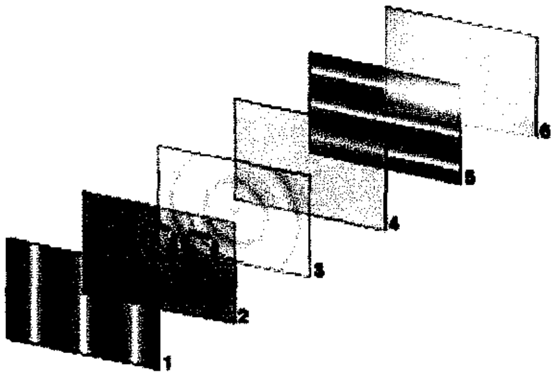


Figure 2 :Reflective twisted nematic liquid crystal display

Figure 3 : General purpose alphanumeric LCD, with two lines of 16 characters

CHAPTER 3
METHODOLOGY AND PROJECT WORK

3.1 Methodology

The TPMS consist of primary components:

i. Sensor

   A pressure sensor is attached together with transmitter to the vehicle's wheel inside the tire's air chamber. The pressure can be measured inside the tyre.

ii. Receiver

   Since the receiver does not have any sensor, so we will place it inside the car. This is to protect the receiver from any damage.

iii. Microcontroller

   Main element in TPMS, brain of the project is microcontroller unit. RfPIC is frequently used in most research. But in this project we finalized to used PIC 16F877 because of special function that this PIC have and this PIC is the most suitable microcontroller for our project.

iv. Output/ display

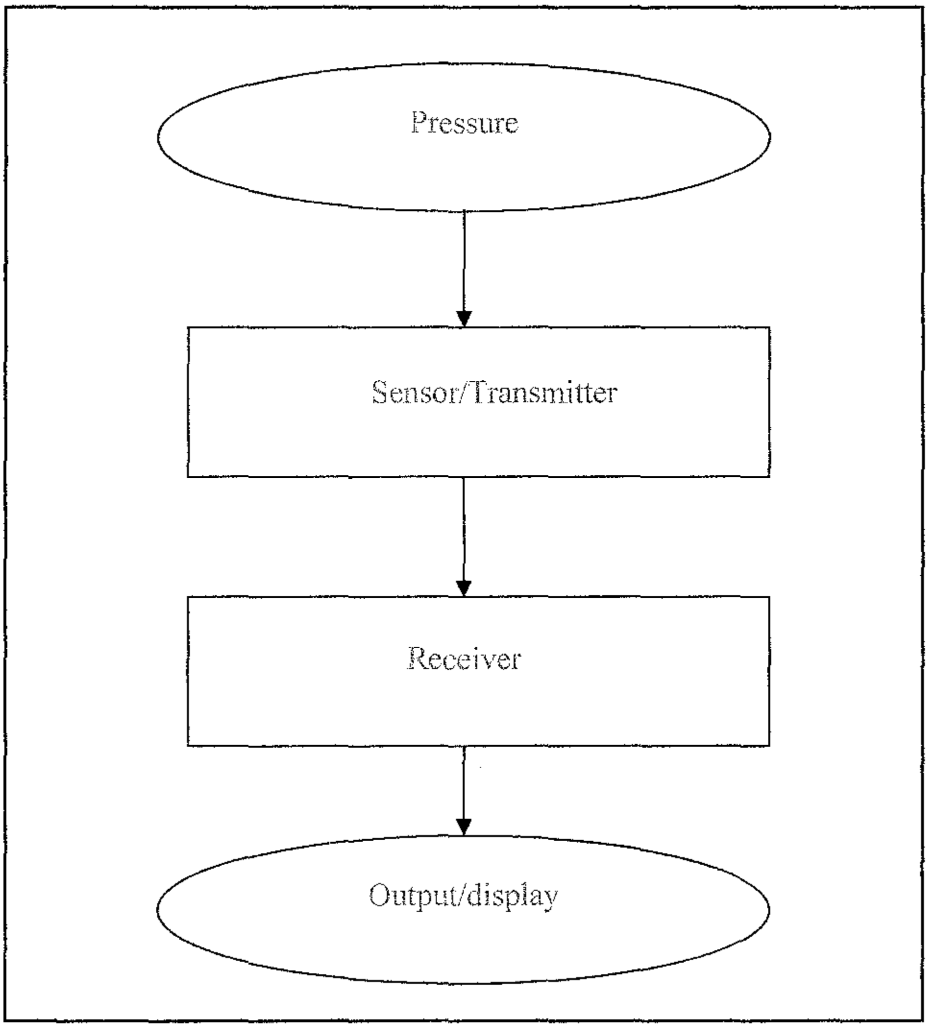


Figure 4 :TPMS basic procedure

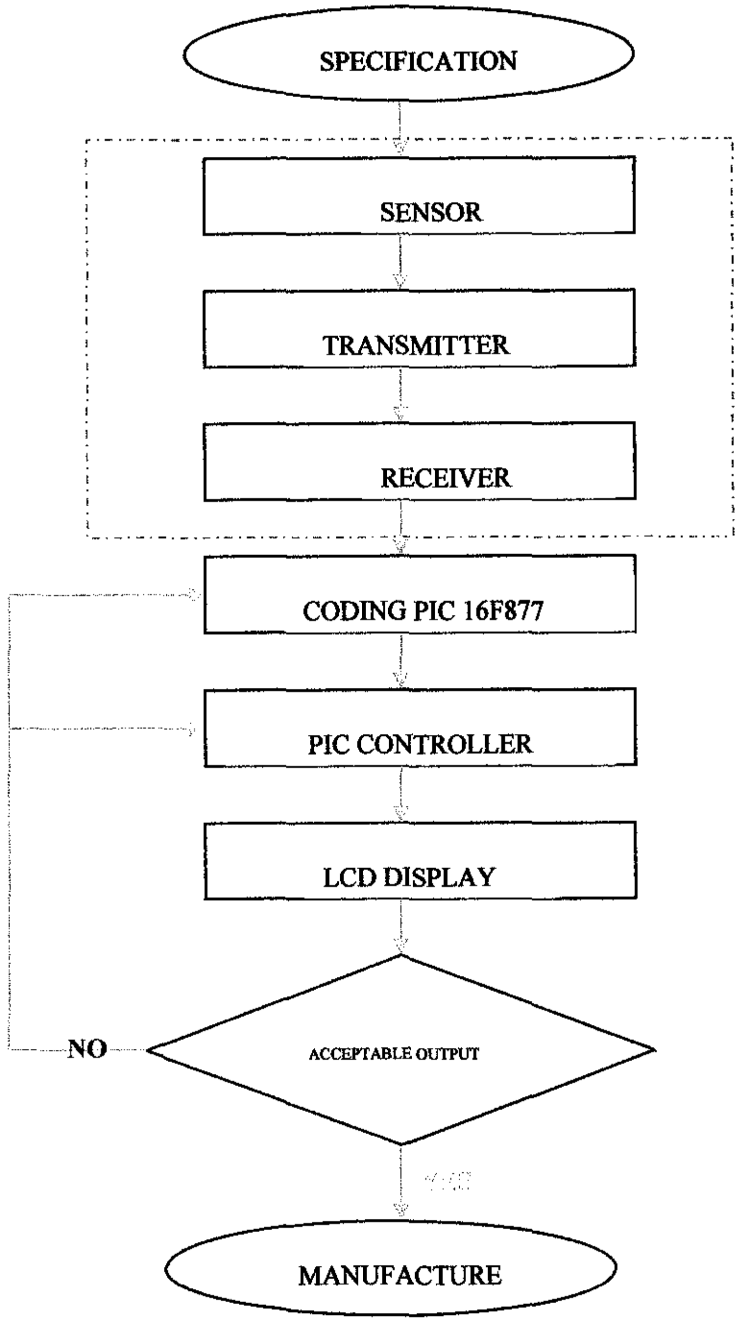


Figure 5 : Logic Flowchart of whole process

The specifications of the project are being identified as the first step in finishing this project. This includes hardware requirement as well as software requirement. Hardware requirements are PIC 16F877, pressure sensor, transmitter, receiver and decoder. Software requirement is a computer programme, such as PIC C.

Firstly, a pressure sensor is needed to sense the pressure from time to time. This sensor is attached together with transmitter to the vehicle's wheel inside the tyre's air chamber. It is then connected to the transmitter. Transmitter is used to transmit the signal to a receiver. A receiver is placed inside the car. This is to protect it from any damage such as vibration, heat and so on. The receiver is connected to a decoder so that it can convert the signal from series to parallel.

PIC16F877 is chosen in this project because it has special function and it is the most suitable microcontroller for this project. In order to make the PIC function according to the requirement, I need to write coding for this PIC, as to the specification and requirement of this project. The specifications are that when the PIC controller processes very low pressure, which is below 100, it will trigger the buzzer and the LCD will display "VERY LOW". If the pressure is from 100 to 200, it will not buzz but only display "LOW" on the LCD display. If the pressure is from 200 to 220, the LCD display will show "NORMAL".

A circuit is designed and the PIC 16F877, LCD display, buzzer and other components are placed on it. The signal from receiver through a decoder is being processed according to the coding of PIC 16F877. The results are then displayed on LCD display. A buzzer is needed so that when the result of the pressure is very low, it will trigger.

When all the circuits and components are put into place and connected accordingly, the project will be tested many times to ensure its reliability. The results obtained need to be acceptable, as far as the requirement and specification is concerned. If the results are not acceptable, troubleshoot either the coding of the PIC 16F877 or the circuit. If there is no problem in the coding, then need to troubleshoot the circuit, to ensure that all the components on the circuit are functioning and there is no short circuit on the circuit itself. Tests are being carried out until desired output is obtained.

The progress of the project has to be supported by facilities, equipments, and components which can be categorized into hardware requirements and software requirements as listed below:

3.2 Hardware Requirements

3.2.1 PIC microcontroller

Main element in TPMS, brain of the project is microcontroller unit. For this project, the microcontroller that being used is PIC 16F877. This is definitely supported by a circuit target board in order to generate desired output.[10]

3.2.2 Tools and Equipments

The tools and equipments in the lab is fully utilize in this project.

3.2.3 Electrical Components

Such components are needed to construct to programming. Components are like PIC 16F877, 4MHz crystal oscillators, voltage regulator, 1 k ohm resistors, push buttons, male and female connectors, buzzer, LEDs and RS 232 chips. [10]

3.2.4 Pressure Sensor

Develop step to step approach on developing miniature pressure sensor

3.2.5 Transmitter

TLP-434 transmitter will be used [15]

3.2.6 Receiver

RLP-434 receiver with frequency 433.92 MHz will be used [16]

3.2.7 Decoder

The decoder receives serial address and data from that series of encoders that are transmitted by the carrier using the RF or an IR transmission medium [13]

3.3 Software Requirements

3.3.1 PIC C Compiler

All software are to be write and compiled on the PIC C COMPILER using C Language. This software will generate the HEX file to be programmed on the particular PIC. [10]

3.3.2 BumbleBee

This is a free ware that is downloaded from the internet to program all type of PIC. Once the HEX file generated is loaded into the software, it is able to program it into the IC through a programmer board that is required to be built.[11]

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Findings

4.1.1 Microcontroller

In order to have a circuit that can monitor the pressure, a transmitter and receiver circuit is enhanced by adding it to microcontroller system. Basically the microcontrollers receive the input from receiver and the outputs are being displayed on the LCD. The digital output of the microcontroller is connected to the LCD segment to display the pressure value and if it too low also, the buzzer will start functioning.

The PIC 16F877 that is chosen for this project has five ports of I/O; A, B, C, D and E. the pin description is given on the table below. This chip provides large data memory that is 368 bytes and has large space for programming.

Pin	Description
1	Reset input and Vpp programming voltage of a microcontroller
2-7	Port A pins
8-10	Port B pins
11,32	Positive power supply
12,31	Ground power supply
13-14	Pin for oscillator
15-18,23-26	Port C pins
19-22,27-30	Port D pins
33-40	Port B pins

Table 2 : Pin description of PIC 16F877[14]

This PIC 16F877 provide built in successive-approximation A/D converter with 10 bit multi-channel where the conversation time faster than digital ramp ADC. There will be 1023 possible step for this converter. This A/D module has high and low voltage reference input in the software selectable to some combination of VDD, Vss, RA2 or RA3.

The A/d converter is assumed to have full scale (F.S) output of 5 V. Therefore, the step size is 5 mV.

Resolution of A/D converter is the smallest unit of measure. The resolution is always equal to the weight of the LSB and referred to as step size. The resolution percentage is 0.1 %

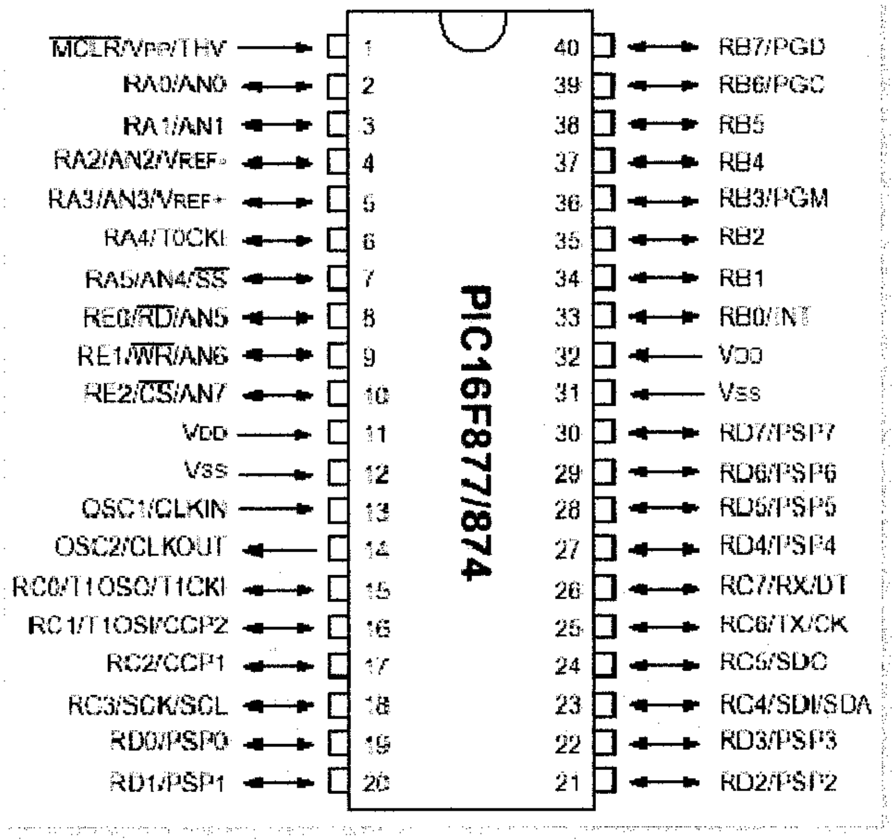


Figure 6 :PIC 16F877[14]

4.1.2 Monitoring Device

The monitoring device is used to display the values or display graph of the parameter such as pressure value. Liquid Crystal Display (LCD) are preferred devices for device because it requires very low current to operate with large screen size. It has 14 pin access with eight data lines, three control lines and three power lines. Pin 4, register select bit is used to select whether data or an instruction is being transferred to and from the module. When the line is low, data bytes transferred to the display and treated as the commands.

For pin 5, this point is set to low in order to write commands and set to high to read status information from its register. Pin 6 is enable line, is used to initiate the actual transfer of commands between the module and the data lines. Pin 7-14 are the eight data bus line. Data can be transferred to and from the module. Only the upper four data is used for latter case. Table below shows the configuration for LCD:

PIN	Description
1	Ground
2	VCC
3	Contrast Voltage
4	R/S instruction/Register select
5	R/W Read/Write LCD register
6	'E' Enable
7-14	Data I/O Pins

Table 3 : Pin configuration of LCD

4.1.3 Decoders[13]

The decoder is a series of LSis for remote control application. There are paired with encoders. For proper operation, a pair of encoders/decoders pair with the same numbers of address and data format should be selected.

The decoder receives serial address and data from that series of encoders that are transmitted by the carrier using the RF or an IR transmission medium. It then compares the serial input data twice continuously with its local address. If no errors or unmatched codes are encountered, the input data will decoded and transferred to output pins. The decoder that being used are HT648L. [13]

Pin Name	I/O	Internal Connection	Description
A0~A17	I	Transmission Gate	Input pin for address setting. They can be externally set to VDD, VSS or left open
D10~D17	O	CMOS OUT	Output Data Pins
DIN	I	CMOS IN	Serial Data input pin
VT	O	CMOS OUT	Valid transmission, active high
OSC 1	I	OSCILLATOR	Oscillator input pin
OSC 2	O	OSCILLATOR	Oscillator output pin
VSS	I	-	Negative power supply (GND)
VDD	I	-	Positive power supply

Table 4 : Pin configuration of decoders [13]

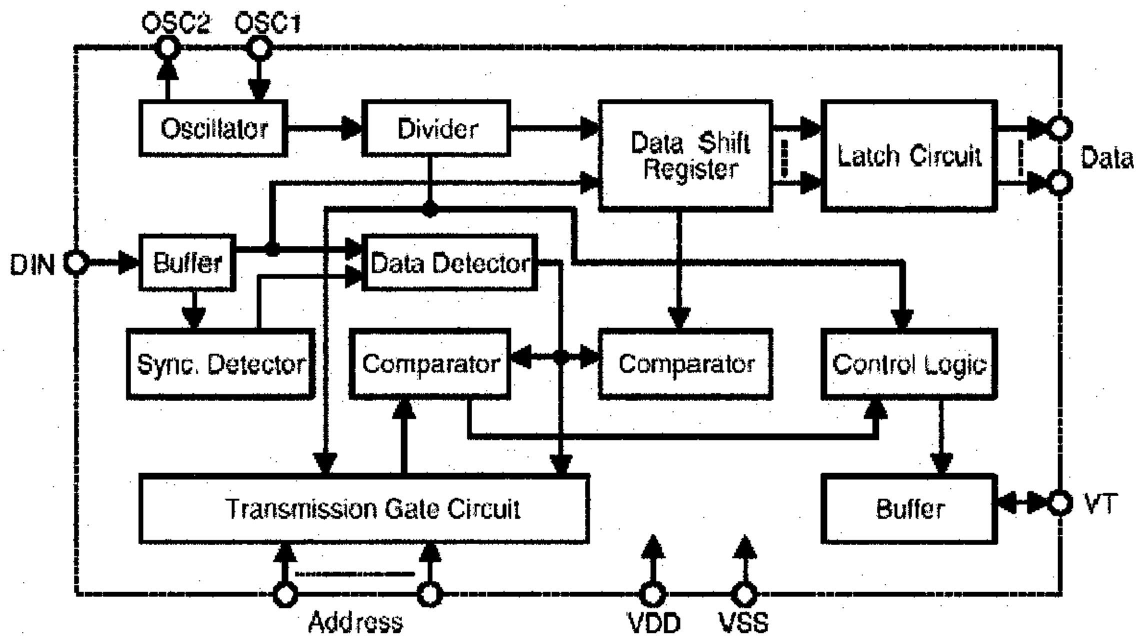


Figure 7 : Address/data pins of decoder are available in various combinations [13]

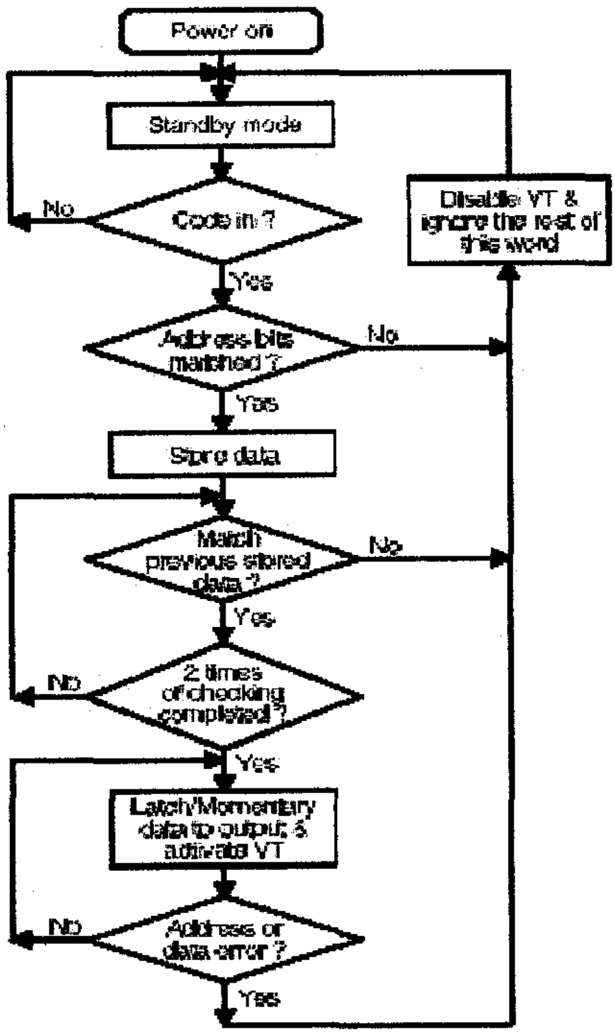


Figure 8 :The oscillator is disabled as a logic "high" signal is applied to the DIN pin

4.2 Discussion

4.2.1 Circuitry design

The PIC is chosen as the desired micro controller in this project because of several various factors. The first is because of its ease of use. It has a very small and limited instruction set. Even though the instruction set is small, it is very fundamental, which allows it to be able to execute complex tasks, if the instruction are strung and executed properly and efficiently. Secondly, the PIC is widely available, because it is a simple chip, easy to use, with high demand all over the world.

The programming board is developed so that the PIC can be easily programmed through the RS 232 on the board connected to the PC using the BumbleBee freeware. This programming board is connected to the PC and also target board which allow the PIC on the target board to be programmed directly without the need of removing the particular microcontroller from its position.[10]

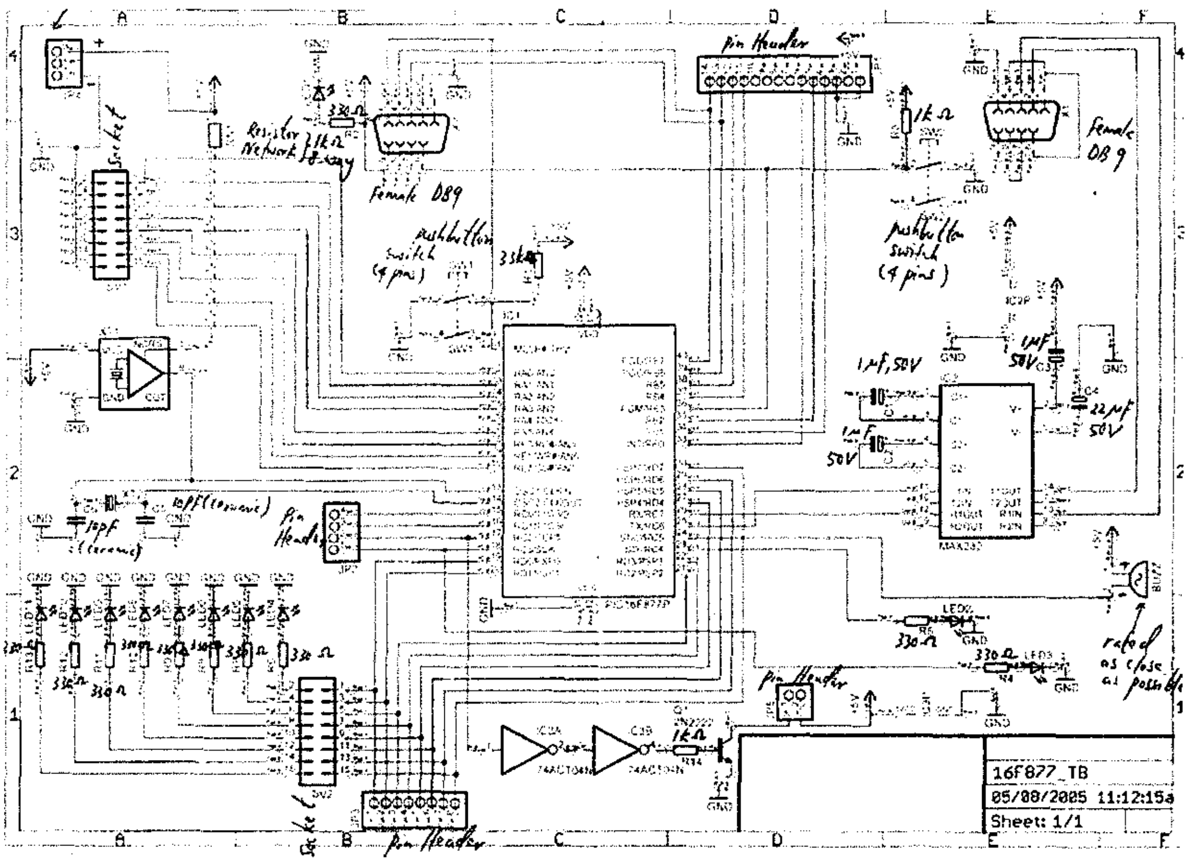


Figure 9 : Circuit produced by Mr. Zuki

The circuit above is the original circuit designed by Mr. Zuki. Mr Zuki had designed the circuit for Microprocessor II project. The circuit can gave the desired output but it is too complicated and many components can just be eliminated. For FYP I, I modify some of the component to make sure that the circuit can display the desired output, and used keypad value as the input. If input from keypad is equal or less than 100, the output on LCD will display **VERY LOW**. This will also trigger buzzer at PIN C5. If the value of input in more than 100 and less than or equal to 200, LCD will display **LOW** and if the value input is more than 200 and less than or equal to 220, LCD will display **NORMAL.**

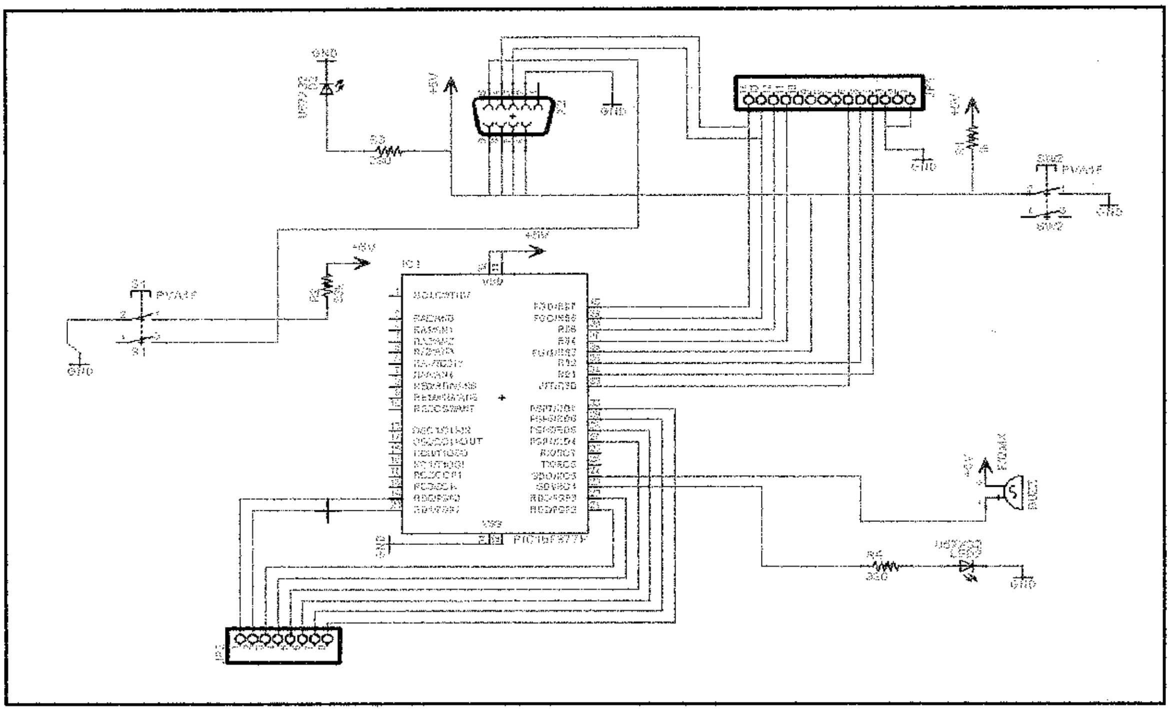


Figure 10 :Modified circuit for FYP I

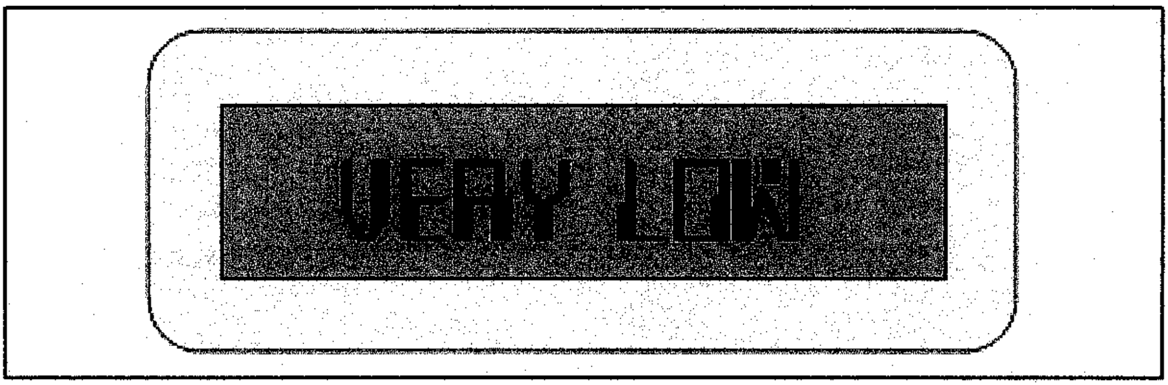


Figure 11 :Example of output display on LCD panel

For this semester, instead of using the input from keypad, we used the input from the receiver. This is because the receiver device is not available last semester. Moreover, using keypad as input during last semester will help to strengthen the basic of knowledge of designed circuit. This semester, we are required to finish our project and produced the real prototype, so I must use the real input from the transmitter and receiver. I also must construct a new coding to program the PIC 16F877 so that we can produce the desired output. For this semester, the signal that being transmitted from receiver is already in digital signal, so the commands in the coding to convert the signal from analogue to digital can be eliminated. After that, the real prototype will be produced and I will combine this project with Mr. Khairul. Figure below shows the modification that going to be made in the circuit

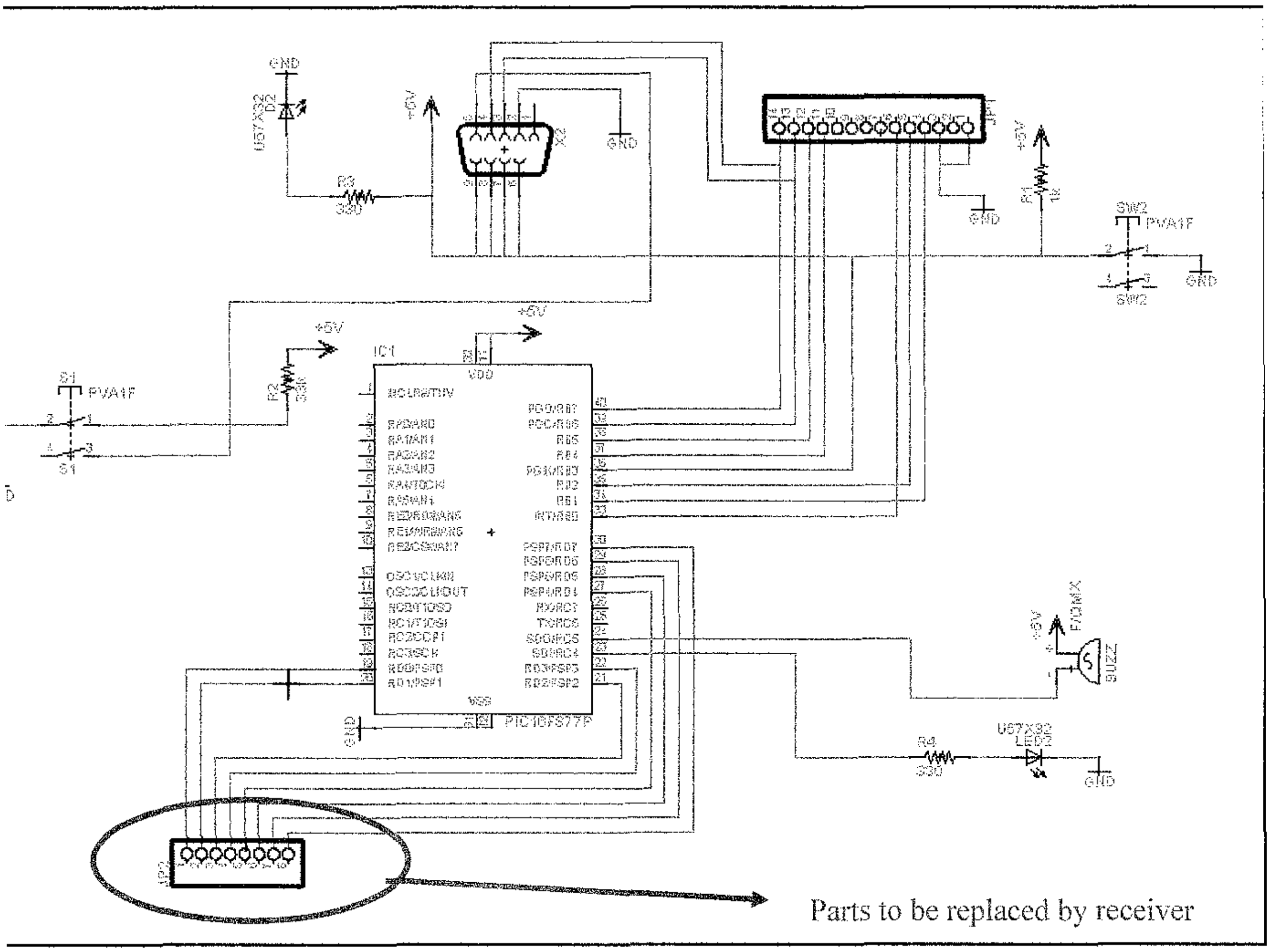


Figure 12 :Modification on the circuit

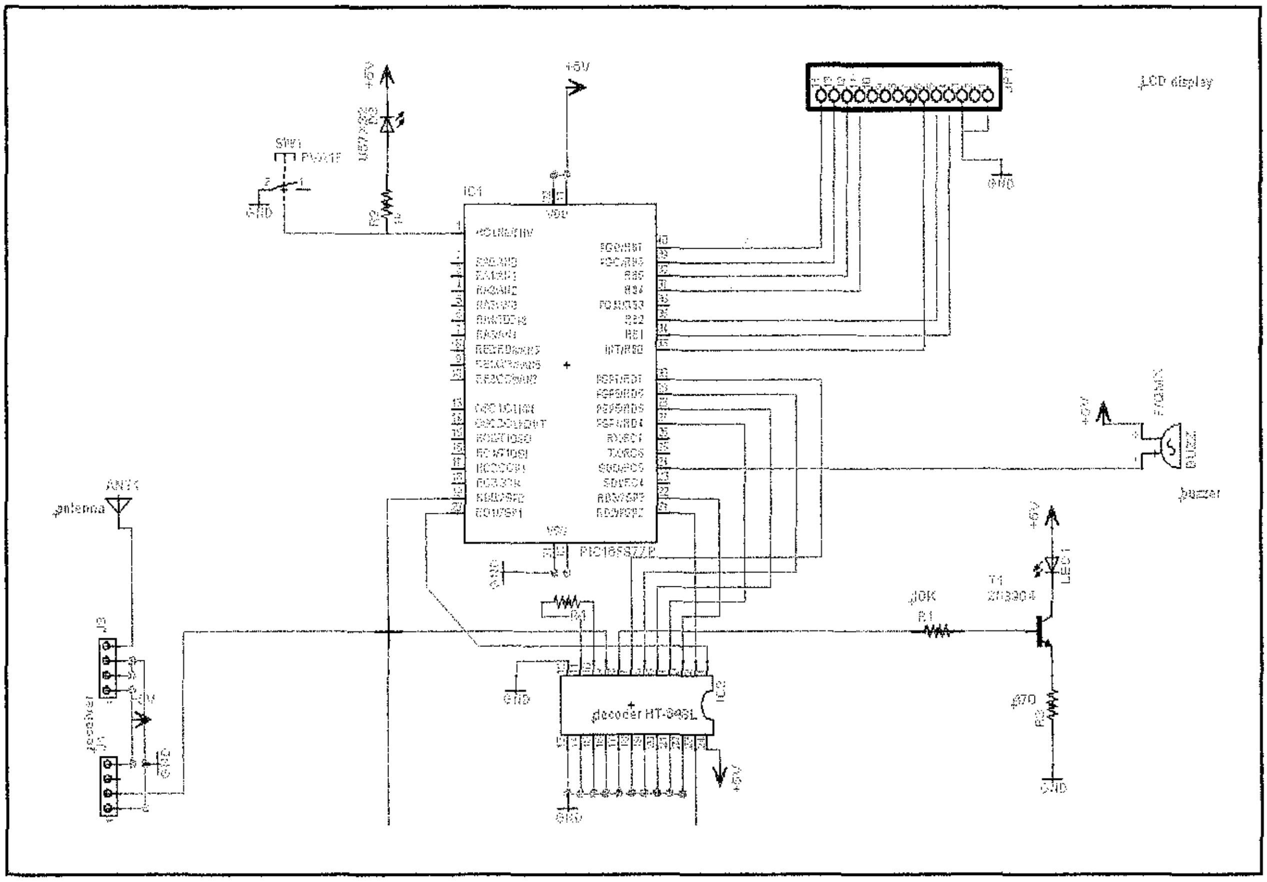


Figure 13 :New circuit for this semester including decoder and receiver

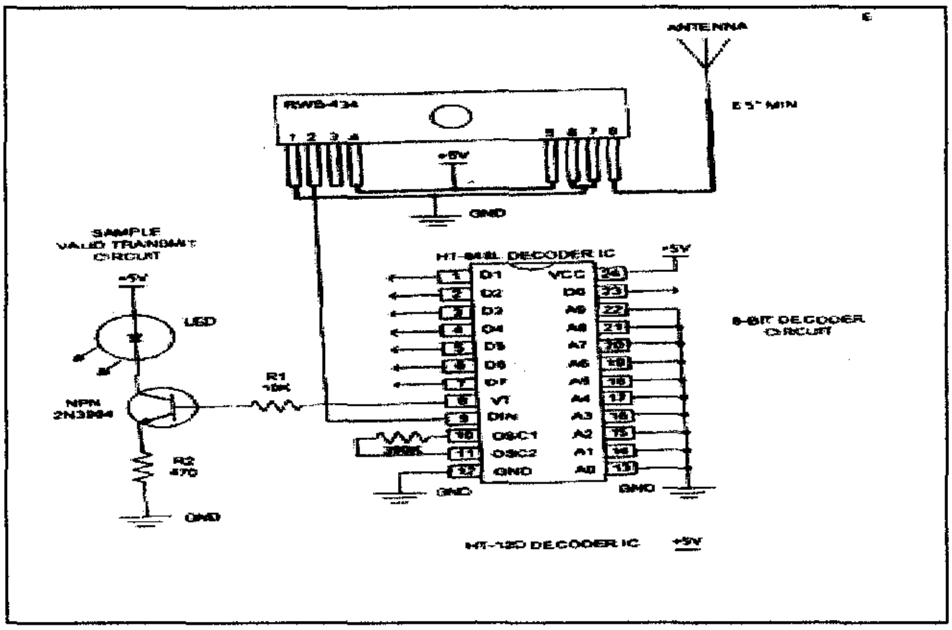


Figure 14 : Circuitry connection between receiver and decoder. [13]

4.2.2 Circuit operation

The sensor on the wheel constantly sends signal about the pressure of the tyre through transmitter to the receiver. The decoder sends the signal as data to the PIC.

When the tyre pressure is below 100kPa (14.5 PSI), it would trigger buzzer that alarms the driver. When the pressure is more than 100kPa but less than 200 kPa (29PSI), the display will show low. And if the pressure is more than 200 kPa the display show normal.

What I can conclude for the circuit operation is:

- Transmitter transmits signals of tyre's pressure from time to time.
- Receiver receives signals and the signals are decoded from serial to parallel.
- The PIC then processes the data according to the specifications.
- The results are displayed on LCD display controlled by the PIC.

CHAPTER 5
CONCLUSION

TPMS should be made standard equipment to the car, not just luxurious cars. This is because through constant monitoring of the tyre pressure, it can help reduce the accidents cause by low tyre pressure. In other word, it can increase the safety of the passengers in the car.

This project was relevant because it can prevent car owner from having accidents just because of the inflated tyres. This is because we can't determine whether the tyre have the sufficient amount of pressure just by looking at the tyre. So by introducing this system, it can help to make sure that the tyres have the sufficient amount of pressure

RECOMMENDATION

- The system can be upgraded with more signals such as the temperature of the tire, which also can be transmitted wirelessly

- Apart from that, a multiplexer for the RF Transmitter to transmit data signals should be implemented in the system instead of using many transmitters

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[16] http://www.laipac.com/rf-receivers.htm

APPENDICES

Appendix A	PIC 16F877 datasheet
Appendix B	Decoder datasheet
Appendix C	Transmitter and Receiver datasheet
Appendix D	Transmitter and Receiver testing range data
Appendix E	Transmitter power datasheet
Appendix F	PIC 16F877 coding (FYP I)
Appendix G	PIC 16F877 coding (FYP II)

Appendix A

PIC 16F877 datasheet

MICROCHIP

PIC16F87X
Data Sheet

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

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PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

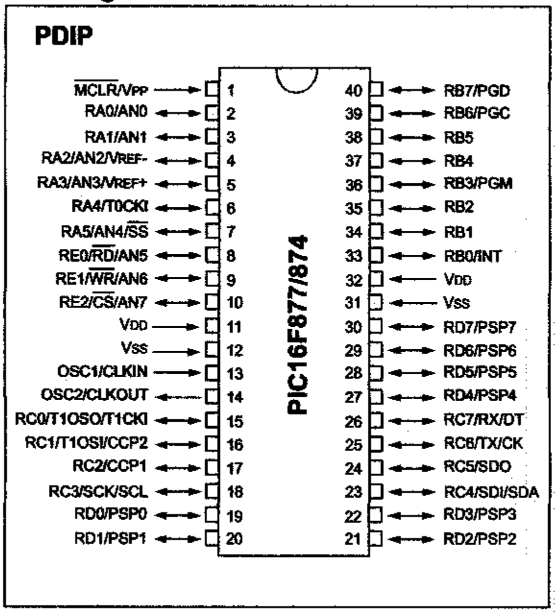
Devices Included in this Data Sheet:

- 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

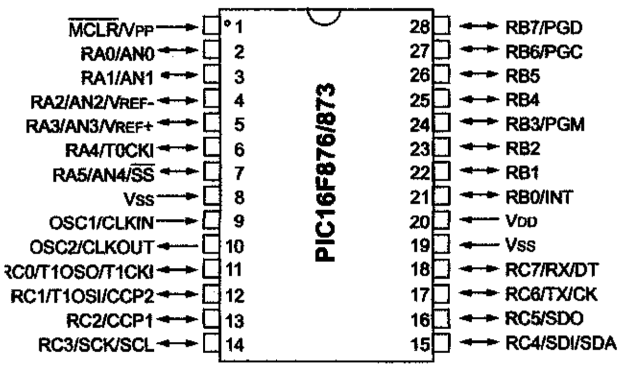


Peripheral Features:

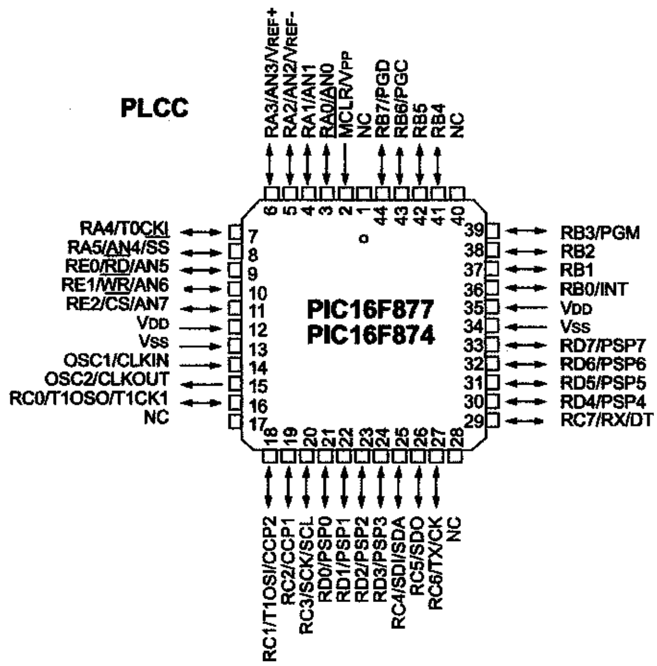
- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. 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 I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

n Diagrams

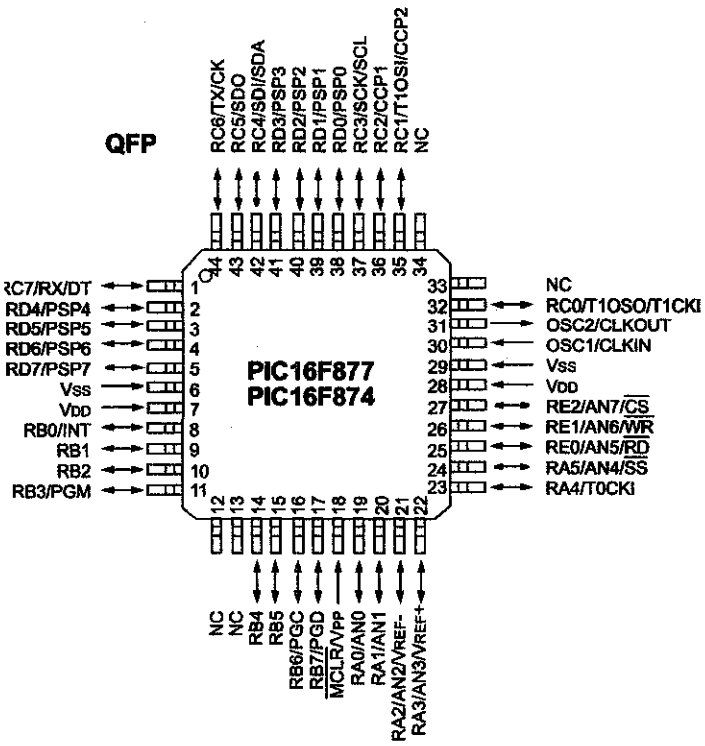
PDIP, SOIC



PLCC



QFP



Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	3	3
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

ıble of Contents

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1.0 DEVICE OVERVIEW

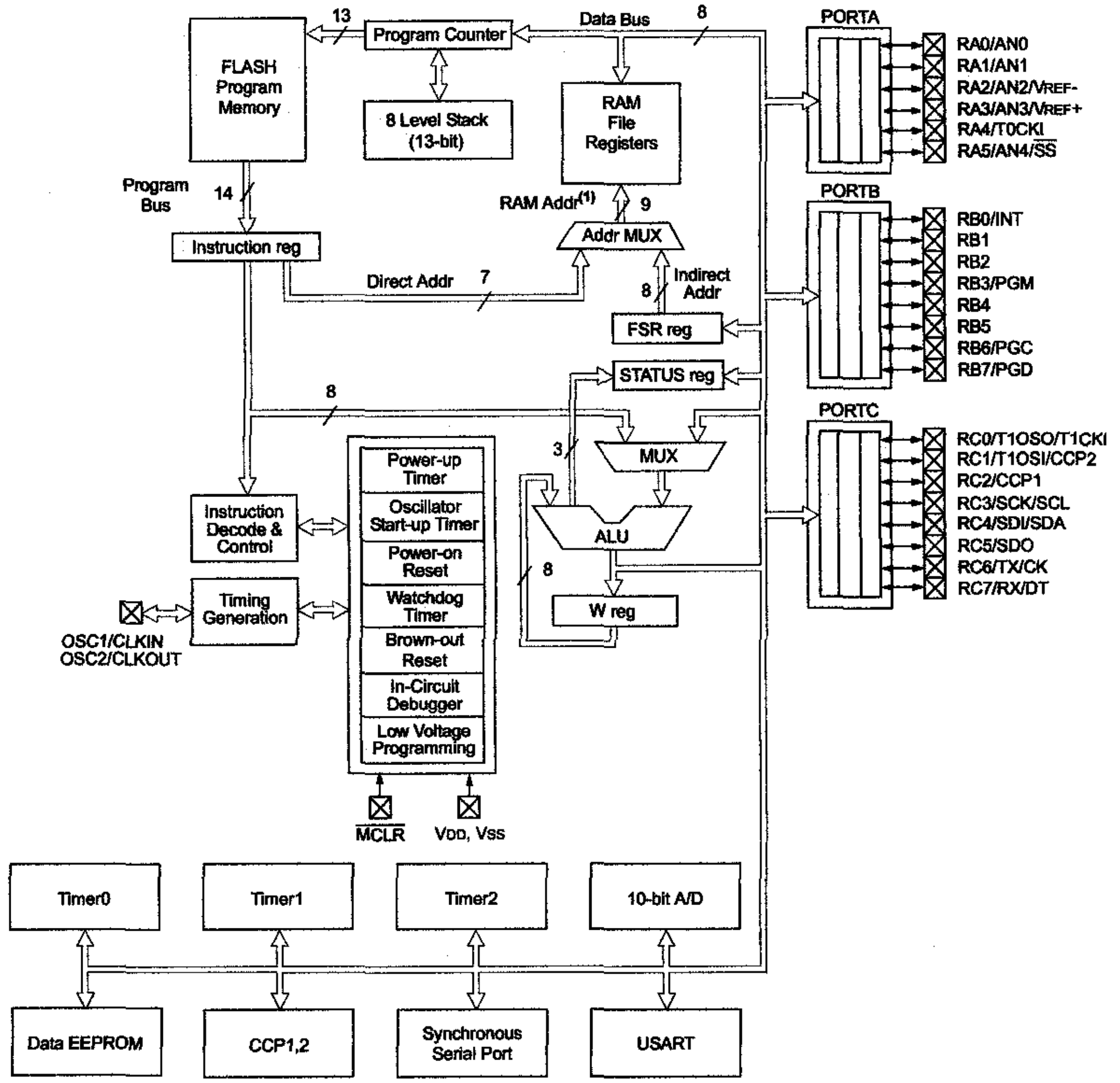
This document contains device specific information. Additional information may be found in the PICmicro™ Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip website. The Reference Manual should be considered a complementary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

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

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

FIGURE 1-1: PIC16F873 AND PIC16F876 BLOCK DIAGRAM

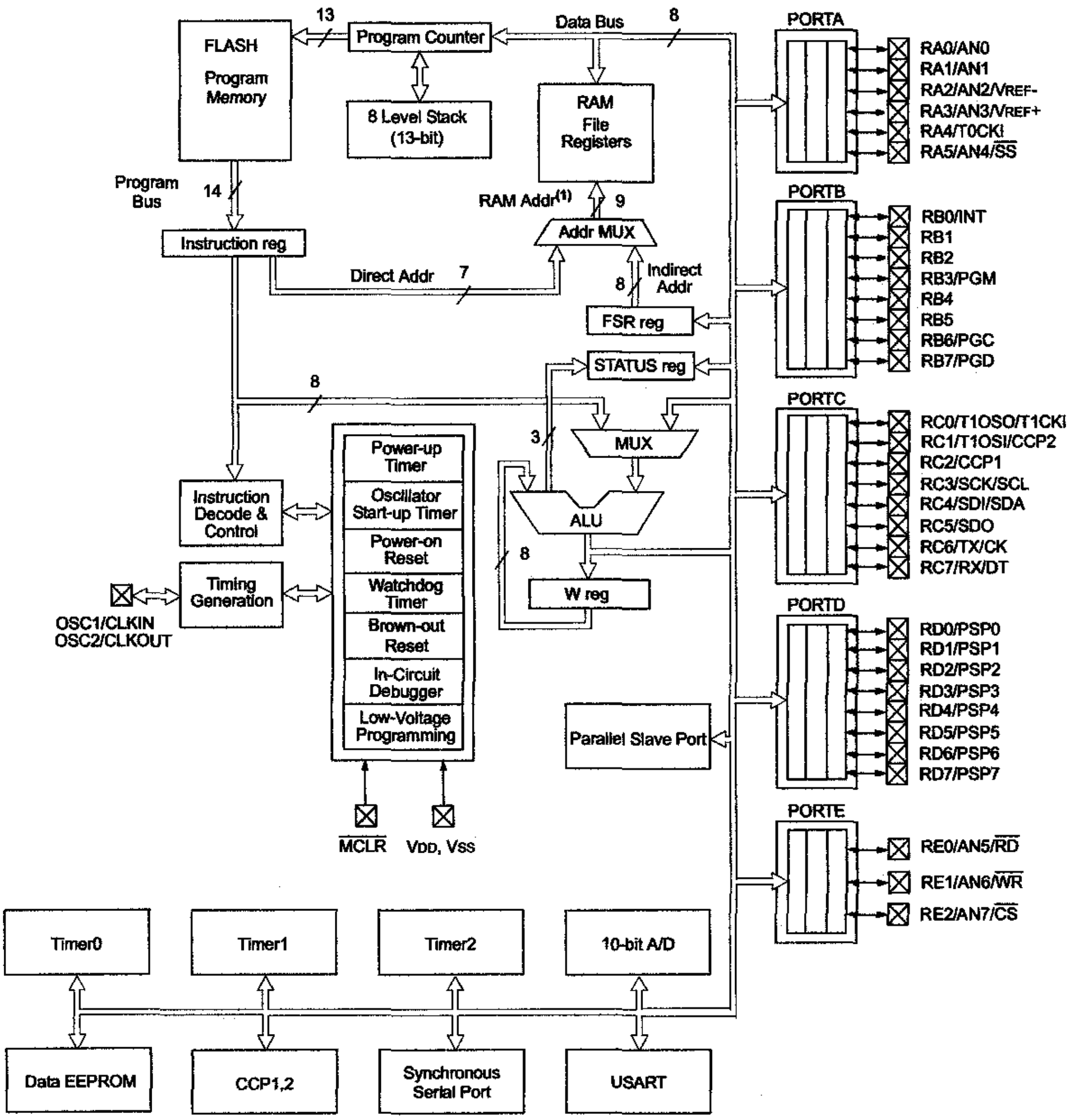
Device	Program FLASH	Data Memory	Data EEPROM
PIC16F873	4K	192 Bytes	128 Bytes
PIC16F876	8K	368 Bytes	256 Bytes



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

GURE 1-2: PIC16F874 AND PIC16F877 BLOCK DIAGRAM

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



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

TABLE 1-1: PIC16F873 AND PIC16F876 PINOUT DESCRIPTION

Pin Name	DIP Pin#	SOIC Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	9	9	I	ST/CMOS(3)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	10	10	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, the OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	1	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	2	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	3	I/O	TTL	RA1 can also be analog input1.
RA2/AN2/VREF-	4	4	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
RA3/AN3/VREF+	5	5	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
RA4/T0CKI	6	6	I/O	ST	RA4 can also be the clock input to the Timer0 module. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	7	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	21	21	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	22	22	I/O	TTL	
RB2	23	23	I/O	TTL	
RB3/PGM	24	24	I/O	TTL	RB3 can also be the low voltage programming input.
RB4	25	25	I/O	TTL	Interrupt-on-change pin.
RB5	26	26	I/O	TTL	Interrupt-on-change pin.
RB6/PGC	27	27	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	28	28	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.
					PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	11	11	I/O	ST	RC0 can also be the Timer1 oscillator output or Timer1 clock input.
RC1/T1OSI/CCP2	12	12	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	13	13	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/ PWM1 output.
RC3/SCK/SCL	14	14	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^{2}C modes.
RC4/SDI/SDA	15	15	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^{2}C mode).
RC5/SDO	16	16	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	17	17	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	18	18	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
VSS	8, 19	8, 19	P	—	Ground reference for logic and I/O pins.
VDD	20	20	P	—	Positive supply for logic and I/O pins.

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 the 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 in RC oscillator mode and a CMOS input otherwise.

BLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
;C1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
;C2/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.
:LR/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.
\0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0.
\1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1.
\2/AN2/VREF-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
\3/AN3/VREF+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
\4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
\5/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.
30/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
31	34	37	9	I/O	TTL	
32	35	38	10	I/O	TTL	
33/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input.
34	37	41	14	I/O	TTL	Interrupt-on-change pin.
35	38	42	15	I/O	TTL	Interrupt-on-change pin.
36/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
37/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.

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

›te 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.

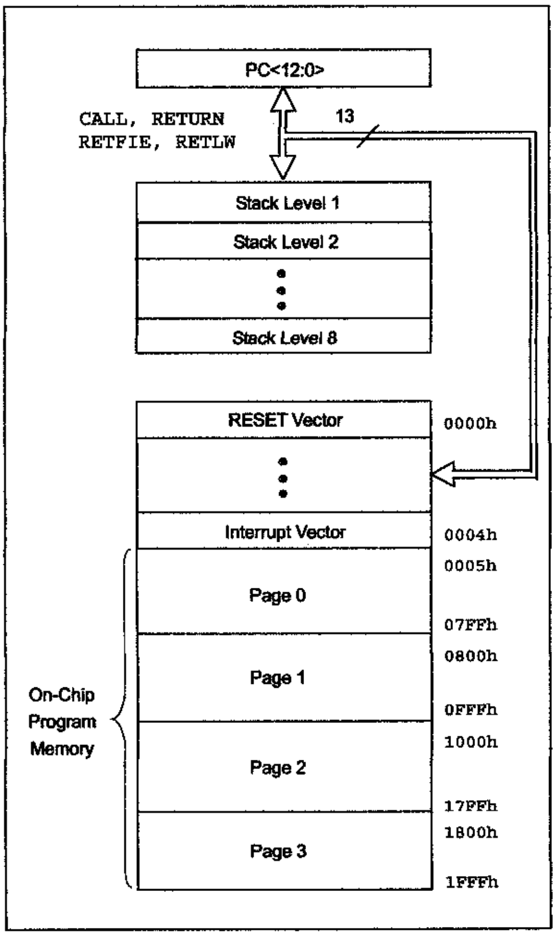
ɔTES:

2.0 MEMORY ORGANIZATION

There are three memory blocks in each of the PIC16F87X MCUs. The Program Memory and Data Memory have separate buses so that concurrent access can occur and is detailed in this section. The EEPROM data memory block is detailed in Section 4.0.

Additional information on device memory may be found in the PICmicro™ Mid-Range Reference Manual, (DS33023).

FIGURE 2-1: PIC16F877/876 PROGRAM MEMORY MAP AND STACK

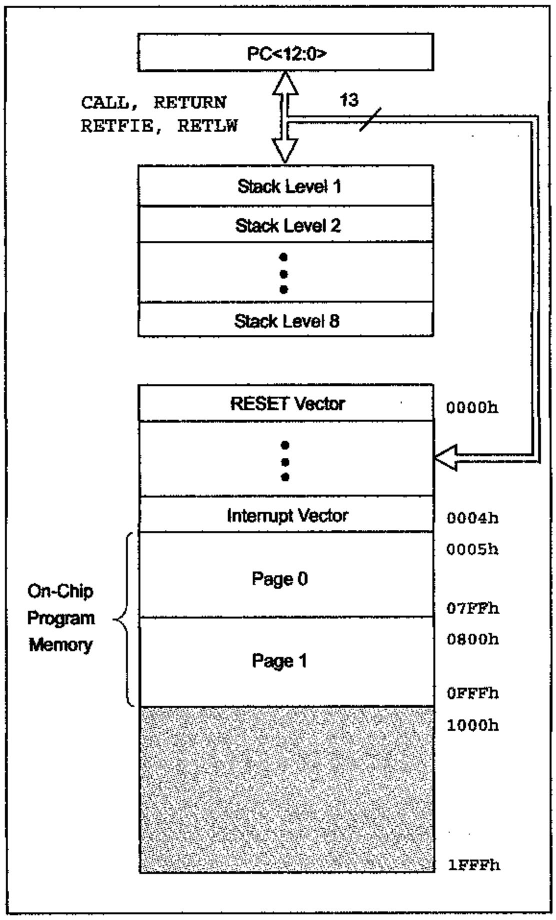


2.1 Program Memory Organization

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 2-2: PIC16F874/873 PROGRAM MEMORY MAP AND STACK



2 Data Memory Organization

e data memory is partitioned into multiple banks ıich contain the General Purpose Registers and the ecial Function Registers. Bits RP1 (STATUS<6>) d RP0 (STATUS<5>) are the bank select bits.

RP1:RP0	Bank
00	0
01	1
10	2
11	3

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.

Note: EEPROM Data Memory description can be found in Section 4.0 of this data sheet.

2.2.1 GENERAL PURPOSE REGISTER FILE

The register file can be accessed either directly, or indirectly through the File Select Register (FSR).

FIGURE 2-3: PIC16F877/876 REGISTER FILE MAP

	File Address		File Address		File Address		File Address
Indirect addr.(*)	00h	Indirect addr.(*)	80h	Indirect addr.(*)	100h	Indirect addr.(*)	180h
TMR0	01h	OPTION_REG	81h	TMR0	101h	OPTION_REG	181h
PCL	02h	PCL	82h	PCL	102h	PCL	182h
STATUS	03h	STATUS	83h	STATUS	103h	STATUS	183h
FSR	04h	FSR	84h	FSR	104h	FSR	184h
PORTA	05h	TRISA	85h		105h		185h
PORTB	06h	TRISB	86h	PORTB	106h	TRISB	186h
PORTC	07h	TRISC	87h		107h		187h
PORTD(1)	08h	TRISD(1)	88h		108h		188h
PORTE(1)	09h	TRISE(1)	89h		109h		189h
PCLATH	0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah
INTCON	0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh
PIR1	0Ch	PIE1	8Ch	EEDATA	10Ch	EECON1	18Ch
PIR2	0Dh	PIE2	8Dh	EEADR	10Dh	EECON2	18Dh
TMR1L	0Eh	PCON	8Eh	EEDATH	10Eh	Reserved(2)	18Eh
TMR1H	0Fh		8Fh	EEADRH	10Fh	Reserved(2)	18Fh
T1CON	10h		90h		110h		190h
TMR2	11h	SSPCON2	91h		111h		191h
T2CON	12h	PR2	92h		112h		192h
SSPBUF	13h	SSPADD	93h		113h		193h
SSPCON	14h	SSPSTAT	94h		114h		194h
CCPR1L	15h		95h		115h		195h
CCPR1H	16h		96h		116h		196h
CCP1CON	17h		97h	General Purpose Register 16 Bytes	117h	General Purpose Register 16 Bytes	197h
RCSTA	18h	TXSTA	98h		118h		198h
TXREG	19h	SPBRG	99h		119h		199h
RCREG	1Ah		9Ah		11Ah		19Ah
CCPR2L	1Bh		9Bh		11Bh		19Bh
CCPR2H	1Ch		9Ch		11Ch		19Ch
CCP2CON	1Dh		9Dh		11Dh		19Dh
ADRESH	1Eh	ADRESL	9Eh		11Eh		19Eh
ADCON0	1Fh	ADCON1	9Fh		11Fh		19Fh
General Purpose Register 96 Bytes	20h	General Purpose Register 80 Bytes	A0h	General Purpose Register 80 Bytes	120h	General Purpose Register 80 Bytes	1A0h
			EFh		16Fh		1EFh
		accesses 70h-7Fh	F0h	accesses 70h-7Fh	170h	accesses 70h - 7Fh	1F0h
	7Fh		FFh		17Fh		1FFh
Bank 0		Bank 1		Bank 2		Bank 3	

▒ Unimplemented data memory locations, read as '0'.
* Not a physical register.

Note 1: These registers are not implemented on the PIC16F876.
2: These registers are reserved, maintain these registers clear.

Appendix B

Decoder datasheet

HOLTEK

3^{18} Series of Decoders

Features

- Operating voltage: 2.4V~12V
- Low power and high noise immunity CMOS technology
- Low standby current
- Capable of decoding 18 bits of information
- Pairs with HOLTEK's 3^{18} series of encoders
- 8~18 address pins
- 0~8 data pins
- Trinary address setting
- Two times of receiving check
- Built-in oscillator needs only a 5% resistor
- Valid transmission indictor
- Easily interface with an RF or an infrared transmission medium
- Minimal external components

Applications

- Burglar alarm system
- Smoke and fire alarm system
- Garage door controllers
- Car door controllers
- Car alarm system
- Security system
- Cordless telephones
- Other remote control systems

General Description

The 3^{18} decoders are a series of CMOS LSIs for remote control system applications. They are paired with the 3^{18} series of encoders. For proper operation a pair of encoder/decoder pair with the same number of address and data format should be selected (refer to the encoder/decoder cross reference tables).

The 3^{18} series of decoders receives serial address and data from that series of encoders that are transmitted by a carrier using an RF or an IR transmission medium. It then compares the serial input data twice continuously with its local address. If no errors or unmatched codes are encountered, the input data codes are decoded and then transferred to the output pins. The VT pin also goes high to indicate a valid transmission.

The 3^{18} decoders are capable of decoding 18 bits of information that consists of N bits of address and 18–N bits of data. To meet various applications they are arranged to provide a number of data pins whose range is from 0 to 8 and an address pin whose range is from 8 to 18. In addition, the 3^{18} decoders provide various combinations of address/data number in different packages.

Selection Table

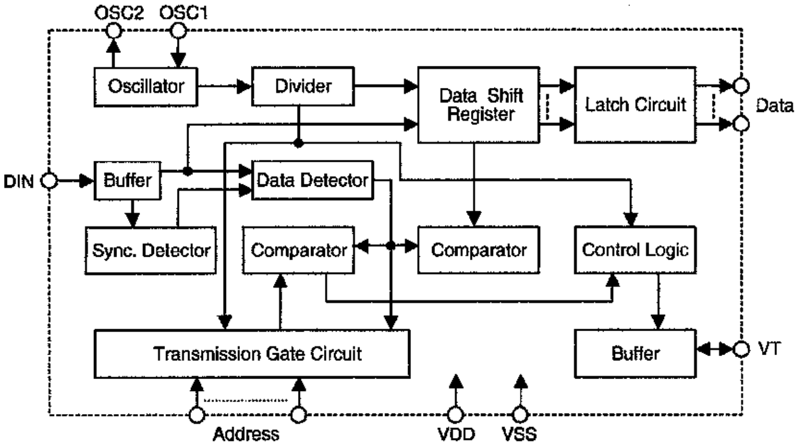
Function / Item	Address No.	Data		VT	Oscillator	Trigger	Package
		No.	Type				
HT602L	12	2	L	√	RC oscillator	DIN active "Hi"	20 DIP/20 SOP
HT604L	10	4	L	√	RC oscillator	DIN active "Hi"	20 DIP/20 SOP
HT605L	9	5	L	√	RC oscillator	DIN active "Hi"	20 DIP/20 SOP
HT611	14	0	—	√	RC oscillator	DIN active "Hi"	20 DIP/20 SOP

Item \ Function	Address No.	Data No.	Data Type	VT	Oscillator	Trigger	Package
HT612	12	2	M	√	RC oscillator	DIN active "Hi"	20 DIP/20 SOP
HT614	10	4	M	√	RC oscillator	DIN active "Hi"	20 DIP/20 SOP
HT615	9	5	M	√	RC oscillator	DIN active "Hi"	20 DIP/20 SOP
HT644L	14	4	L	√	RC oscillator	DIN active "Hi"	24 SOP/24 SDIP
HT646L	12	6	L	√	RC oscillator	DIN active "Hi"	24 SOP/24 SDIP
HT648L	10	8	L	√	RC oscillator	DIN active "Hi"	24 SOP/24 SDIP
HT651	18	0	—	√	RC oscillator	DIN active "Hi"	24 SOP/24 SDIP
HT654	14	4	M	√	RC oscillator	DIN active "Hi"	24 SOP/24 SDIP
HT656	12	6	M	√	RC oscillator	DIN active "Hi"	24 SOP/24 SDIP
HT658	10	8	M	√	RC oscillator	DIN active "Hi"	24 SOP/24 SDIP
HT682L	10	2	L	√	RC oscillator	DIN active "Hi"	18 DIP
HT683L	9	3	L	√	RC oscillator	DIN active "Hi"	18 DIP
HT684L	8	4	L	√	RC oscillator	DIN active "Hi"	18 DIP
HT691	12	0	—	√	RC oscillator	DIN active "Hi"	18 DIP
HT692	10	2	M	√	RC oscillator	DIN active "Hi"	18 DIP
HT693	9	3	M	√	RC oscillator	DIN active "Hi"	18 DIP
HT694	8	4	M	√	RC oscillator	DIN active "Hi"	18 DIP

Note: Data type: M represents momentary type of data output.
L represents latch type of data output.

VT can be used as a momentary data output.

Block Diagram

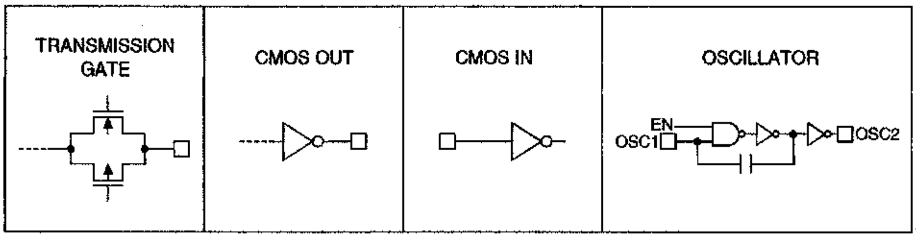


Note: The address/data pins are available in various combinations (refer to the address/data table).

Pin Description

Pin Name	I/O	Internal Connection	Description
A0~A17	I	TRANSMISSION GATE	Input pins for address A0~A17 setting They can be externally set to VDD, VSS, or left open.
D10~D17	O	CMOS OUT	Output data pins
DIN	I	CMOS IN	Serial data input pin
VT	O	CMOS OUT	Valid transmission, active high
OSC1	I	OSCILLATOR	Oscillator input pin
OSC2	O	OSCILLATOR	Oscillator output pin
VSS	I	—	Negative power supply (GND)
VDD	I	—	Positive power supply

Approximate internal connection circuits



Absolute Maximum Ratings*

Supply Voltage .... –0.3V to 13V

Input Voltage.................. V_{SS}–0.3V to V_{DD}+0.3V

Storage Temperature................. –50°C to 125°C

Operating Temperature.............. –20°C to 75°C

*Note: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of this device at these or any other conditions above those indicated in the operational sections of this specification is not implied and exposure to absolute maximum rating conditions for extened periods may affect device reliability.

Electrical Characteristics

(Ta=25°C)

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Operating Voltage	—	—	3	—	12	V
I_{STB}	Standby Current	5V	Oscillator stops	—	0.1	1	µA
		12V		—	2	4	µA
I_{DD}	Operating Current	5V	No load F_{OSC}=100kHz	—	0.2	1	mA
I_O	Data Output Source Current (D10~D17)	5V	V_{OH}=4.5V	–0.5	–1	—	mA
	Data Output Sink Current (D10~D17)		V_{OL}=0.5V	0.5	1	—	mA
I_{VT}	VT Output Source Current	5V	V_{OH}=4.5V	–2	–4	—	mA
	VT Output Sink Current		V_{OL}=0.5V	1	2	—	mA
V_{IH}	"H" Input Voltage	5V	—	3.5	—	5	V
V_{IL}	"L" Input Voltage	5V	—	0	—	1	V
F_{OSC}	Oscillator Frequency	10V	R_{OSC}=330kΩ	—	100	—	kHz

Functional Description

Operation

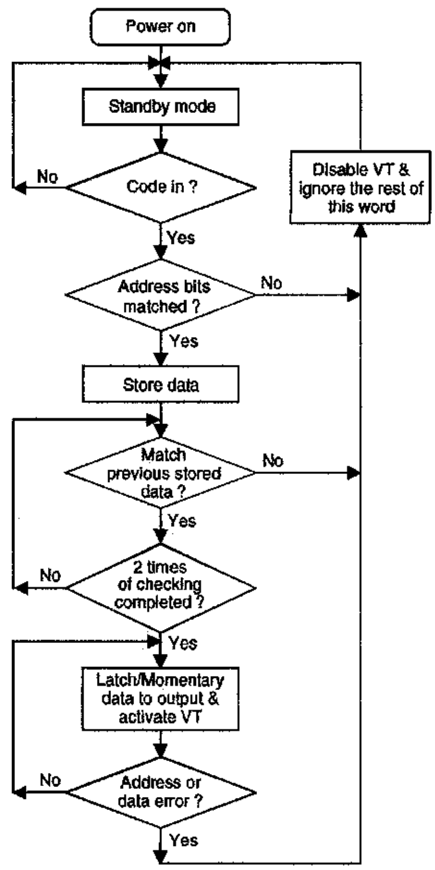
The 3^{18} series of decoders provides various combinations of address and data pins in different packages. It is paired with the 3^{18} series of encoders. The decoders receive data transmitted by the encoders and interpret the first N bits of the code period as address and the last 18–N bits as data (where N is the address code number). A signal on the DIN pin then activates the oscillator which in turns decodes the incoming address and data. The decoders will check the received address twice continuously. If all the received address codes match the contents of the decoder's local address, the 18–N bits of data are decoded to activate the output pins, and the VT pin is set high to indicate a valid transmission. That will last until the address code is incorrect or no signal has been received. The output of the VT pin is high only when the transmission is valid. Otherwise it is low always.

Output type

There are 2 types of output to select from:

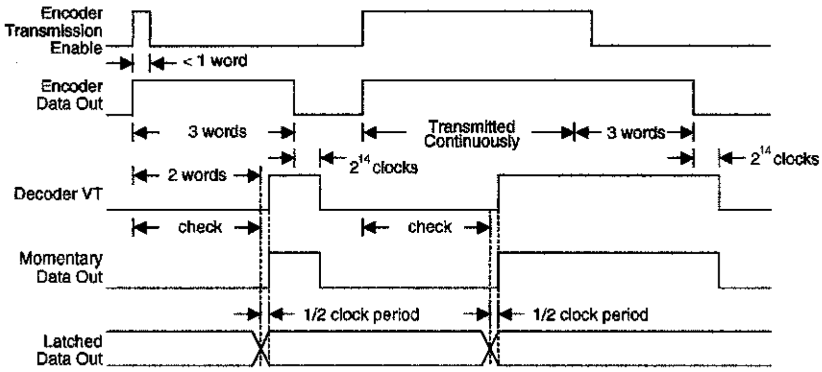
- Momentary type
  The data outputs follow the encoder during a valid transmission and then reset.
- Latch type
  The data outputs follow the encoder during a valid transmission, and are then latched in this state until the next valid transmission occurs.

Flowchart



Note: The oscillator is disabled in the standby state and activated as long as a logic "high" signal is applied to the DIN pin. i.e., the DIN should be kept "low" if there is no signal input.

Decoder timing



Encoder/Decoder selection tables

• Latch type of data output

Part No.	Data Pins	Address Pins	VT	Pair Encoder	Package					
					Encoder			Decoder		
					DIP	SOP	SDIP	DIP	SOP	SDIP
HT682L	2	10	√	HT680	18	—	—	18	—	—
HT683L	3	9	√	HT680	18	—	—	18	—	—
				HT6187	18	—				
HT684L	4	8	√	HT680	18	—	—	18	—	—
HT602L	2	12	√	HT600	20	20	—	20	20	—
HT604L	4	10	√	HT600	20	20	—	20	20	—
				HT6207	20	—				
HT605L	5	9	√	HT600	20	20	—	20	20	—
HT644L	4	14	√	HT640	24	24	24	—	24	24
HT646L	6	12	√	HT640	24	24	24	—	24	24
				HT6247	24	—				
HT648L	8	10	√	HT640	24	24	24	—	24	24

• Momentary type of data output

Part No.	Data Pins	Address Pins	VT	Pair Encoder	Package					
					Encoder			Decoder		
					DIP	SOP	SDIP	DIP	SOP	SDIP
HT691	0	12	√	HT680	18	—	—	18	—	—
HT692	2	10	√	HT680	18	—	—	18	—	—
HT693	3	9	√	HT680	18	—	—	18	—	—
				HT6187	18	—				
HT694	4	8	√	HT680	18	—	—	18	—	—
HT611	0	14	√	HT600	20	20	—	20	20	—
HT612	2	12	√	HT600	20	20	—	20	20	—
HT614	4	10	√	HT600	20	20	—	20	20	—
				HT6207	20	—				
HT615	5	9	√	HT600	20	20	—	20	20	—
HT651	0	18	√	HT640	24	24	24	—	24	24
HT654	4	14	√	HT640	24	24	24	—	24	24
HT656	6	12	√	HT640	24	24	24	—	24	24
				HT6247	24	—				
HT658	8	10	√	HT640	24	24	24	—	24	24

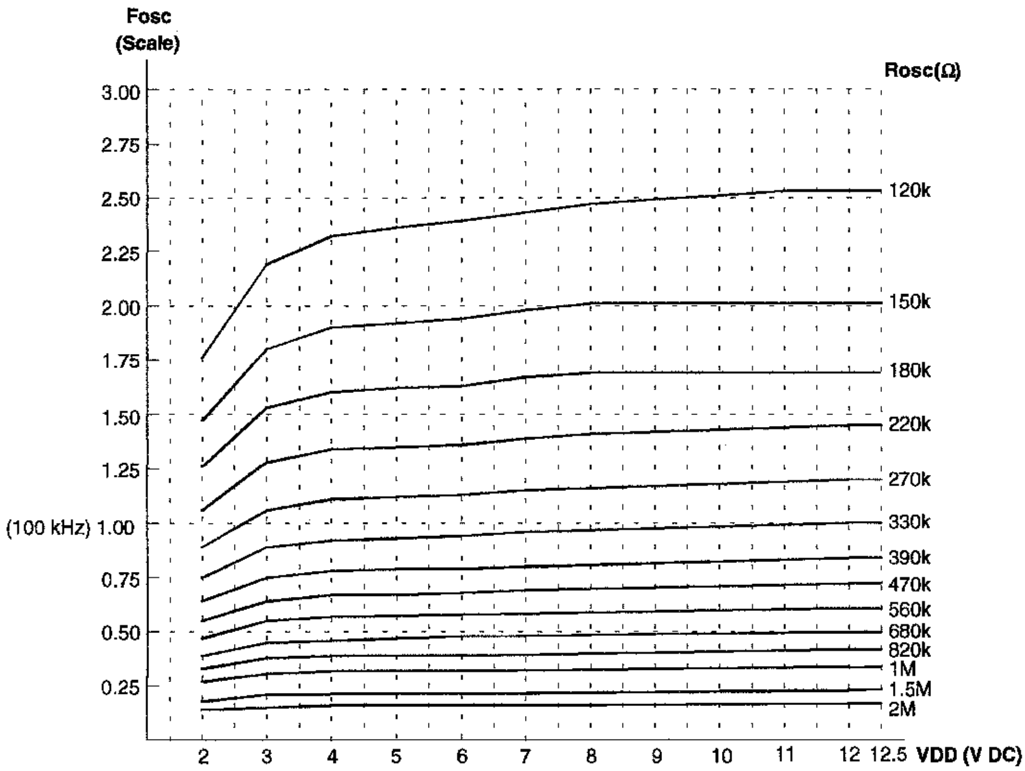
Address/Data sequence

The following provides a table of address/data sequence for various models of the 3^{18} series decoders. A correct device should be selected according to the requirements of individual address and data.

Part No.	Address/Data Bits										
	0~3	4	5	6~9	10	11	12	13	14	15	16	17
HT602L	A0~A3	A4	—	A6~A9	—	A11	A12	A13	D14	D15	—	—
HT604L	A0~A3	A4	—	A6~A9	—	A11	D12	D13	D14	D15	—	—
HT605L	A0~A3	A4	—	A6~A9	—	D11	D12	D13	D14	D15	—	—
HT611	A0~A3	A4	—	A6~A9	—	A11	A12	A13	A14	A15	—	—
HT612	A0~A3	A4	—	A6~A9	—	A11	A12	A13	D14	D15	—	—
HT614	A0~A3	A4	—	A6~A9	—	A11	D12	D13	D14	D15	—	—
HT615	A0~A3	A4	—	A6~A9	—	D11	D12	D13	D14	D15	—	—
HT644L	A0~A3	A4	A5	A6~A9	A10	A11	A12	A13	D14	D15	D16	D17
HT646L	A0~A3	A4	A5	A6~A9	A10	A11	D12	D13	D14	D15	D16	D17
HT648L	A0~A3	A4	A5	A6~A9	D10	D11	D12	D13	D14	D15	D16	D17
HT651	A0~A3	A4	A5	A6~A9	A10	A11	A12	A13	A14	A15	A16	A17
HT654	A0~A3	A4	A5	A6~A9	A10	A11	A12	A13	D14	D15	D16	D17
HT656	A0~A3	A4	A5	A6~A9	A10	A11	D12	D13	D14	D15	D16	D17
HT658	A0~A3	A4	A5	A6~A9	D10	D11	D12	D13	D14	D15	D16	D17
HT682L	A0~A3	—	—	A6~A9	—	A11	A12	—	D14	D15	—	—
HT683L	A0~A3	—	—	A6~A9	—	A11	D12	—	D14	D15	—	—
HT684L	A0~A3	—	—	A6~A9	—	D11	D12	—	D14	D15	—	—
HT691	A0~A3	—	—	A6~A9	—	A11	A12	—	A14	A15	—	—
HT692	A0~A3	—	—	A6~A9	—	A11	A12	—	D14	D15	—	—
HT693	A0~A3	—	—	A6~A9	—	A11	D12	—	D14	D15	—	—
HT694	A0~A3	—	—	A6~A9	—	D11	D12	—	D14	D15	—	—

Note: "—" is a dummy code which is left "open" and not bonded out.

Oscillator frequency vs supply voltage

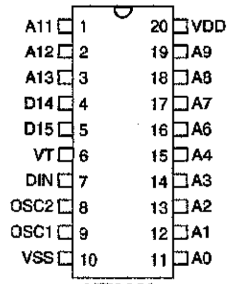


The recommended oscillator frequency is FOSCD (decoder) ≅ FOSCE (encoder).

Package Information

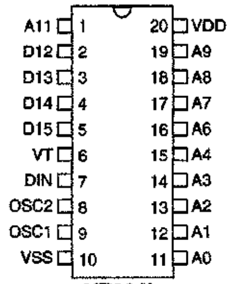
Latch series

12-Address 2-Data



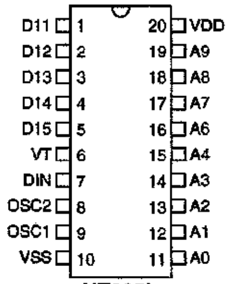
HT602L – 20 DIP/SOP

10-Address 4-Data



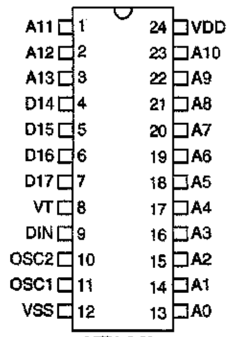
HT604L – 20 DIP/SOP

9-Address 5-Data



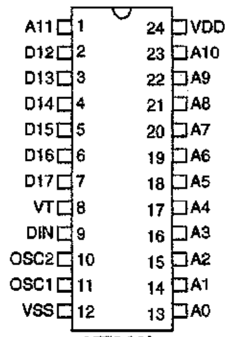
HT605L – 20 DIP/SOP

14-Address 4-Data



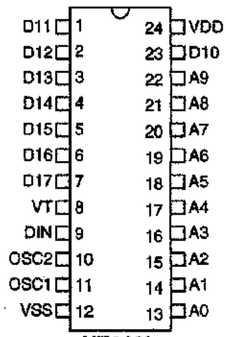
HT644L – 24 SOP/SDIP

12-Address 6-Data



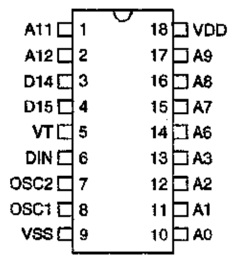
HT646L – 24 SOP/SDIP

10-Address 8-Data



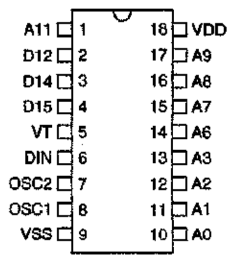
HT648L – 24 SOP/SDIP

10-Address 2-Data



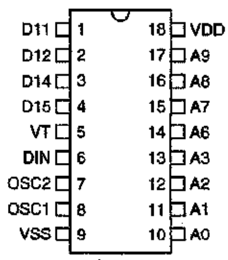
HT682L – 18 DIP

9-Address 3-Data



HT683L – 18 DIP

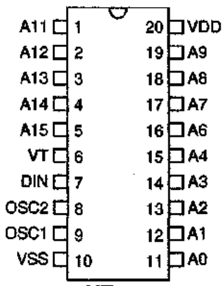
8-Address 4-Data



HT684L – 18 DIP

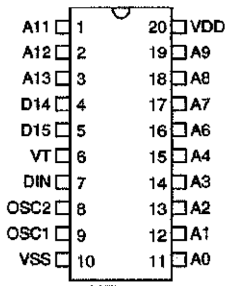
Momentary series

14-Address
0-Data



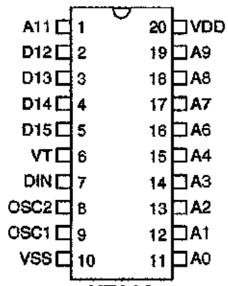
HT611
– 20 DIP/SOP

12-Address
2-Data



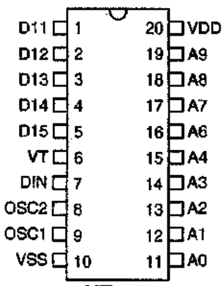
HT612
– 20 DIP/SOP

10-Address
4-Data



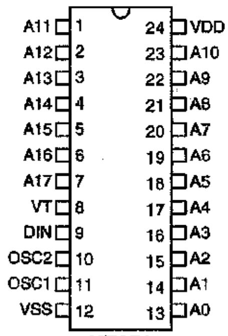
HT614
– 20 DIP/SOP

9-Address
5-Data



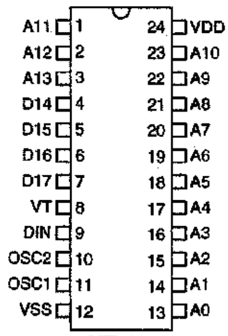
HT615
– 20 DIP/SOP

18-Address
0-Data



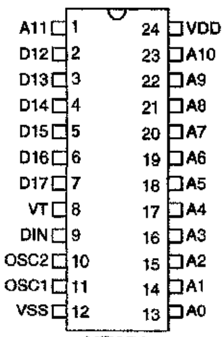
HT651
– 24 SOP/SDIP

14-Address
4-Data



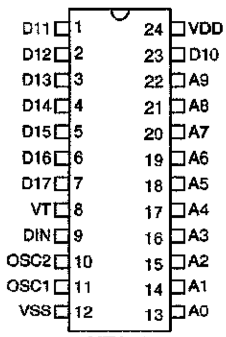
HT654
– 24 SOP/SDIP

12-Address
6-Data



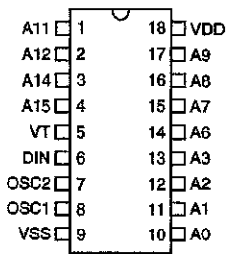
HT656
– 24 SOP/SDIP

10-Address
8-Data



HT658
– 24 SOP/SDIP

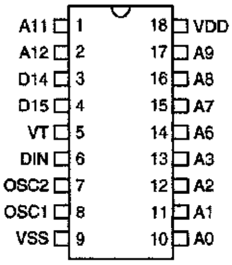
12-Address
0-Data



HT691
– 18 DIP

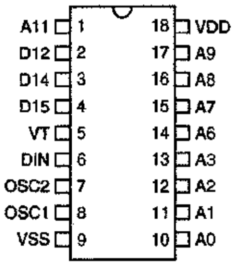
Momentary series

10-Address
2-Data



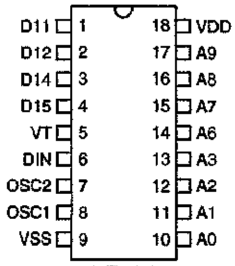
HT692
– 18 DIP

9-Address
3-Data



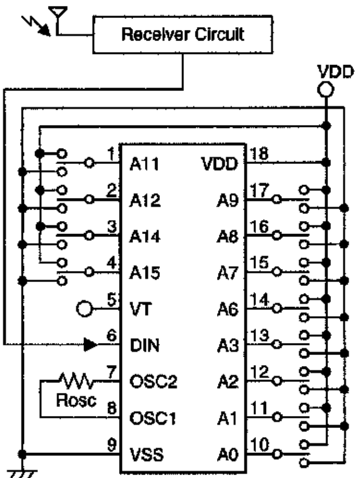
HT693
– 18 DIP

8-Address
4-Data

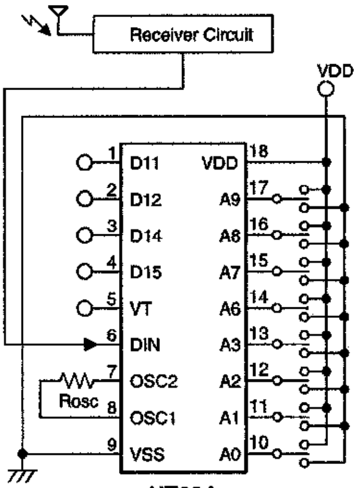


HT694
– 18 DIP

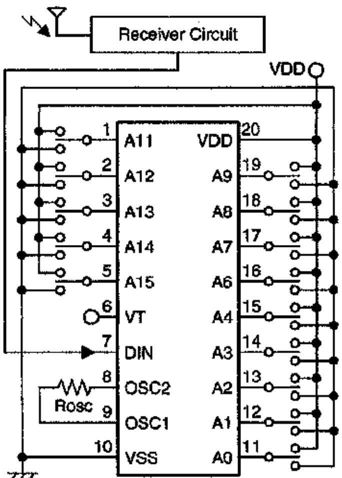
Application Circuits



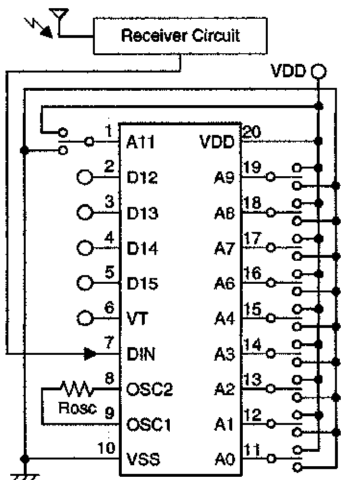
HT691



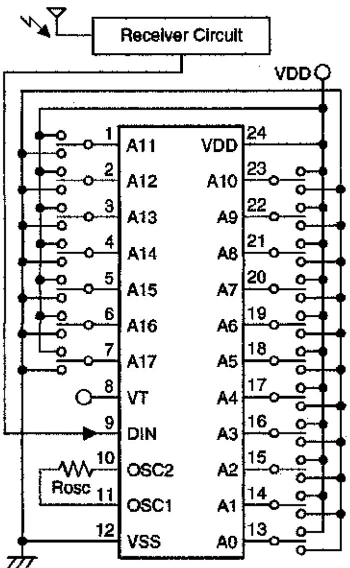
HT694



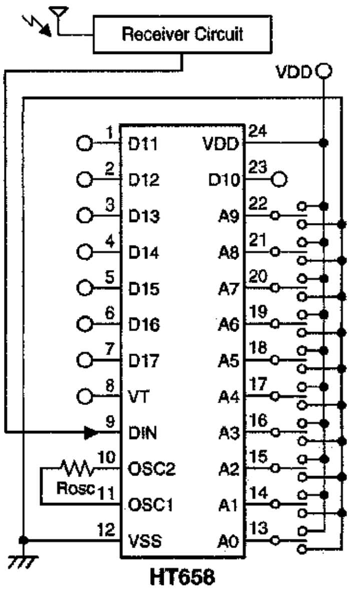
HT611



HT614



HT651



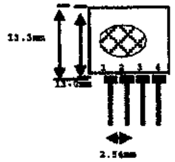
HT658

Note: Typical infrared receiver: PIC-12043T/PIC-12043C (KODENSHI CORP.)
or LTM9052 (LITEON CORP.)
Typical RF receiver: JR-200 (JUWA CORP.)
RE-99 (MING MICROSYSTEM, U.S.A.)

Appendix C

Transmitter and Receiver datasheet

Easy-Link Wireless



pin 1 : GND
pin 2 : Data In
pin 3 : Vcc
pin 4 : Antenna (RF output)

Frequency 315, 418 and 433.92 Mhz

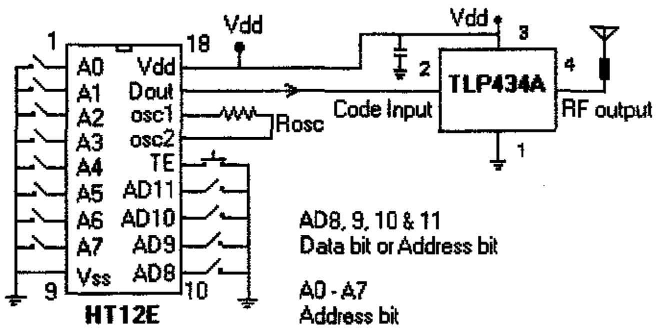
Modulation : ASK
Operation Voltage : 2 - 12 VDC

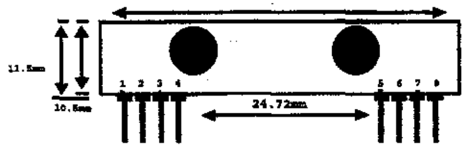
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Vcc	Operating supply voltage		2.0	-	12.0	V
Icc 1	Peak Current (2V)		-	-	1.64	mA
Icc 2	Peak Current (12V)		-	-	19.4	mA
Vh	Input High Voltage	Idata= 100uA (High)	Vcc-0.5	Vcc	Vcc+0.5	V
Vl	Input Low Voltage	Idata= 0 uA (Low)	-	-	0.3	V
FO	Absolute Frequency	315Mhz module	314.8	315	315.2	MHz
PO	RF Output Power- 50ohm	Vcc = 9V-12V	-	16	-	dBm
		Vcc = 5V-6V	-	14	-	dBm
DR	Data Rate	External Encoding	512	4.8K	200K	bps

Notes : (Case Temperature = 25°C +- 2°C , Test Load Impedance = 50 ohm)

Application Circuit :

Typical Key-chain Transmitter using HT12E-18DIP, a Binary 12 bit Encoder from Holtek Semiconductor Inc.





pin 2 : Digital Data Output
pin 3 : Linear Output /Test
pin 4 : Vcc
pin 5 : Vcc
pin 6 : Gnd
pin 7 : Gnd
pin 8 : Antenna

Frequency 315, 418 and 433.92 Mhz

Modulation : ASK
Supply Voltage : 3.3 - 6.0 VDC
Output : Digital & Linear

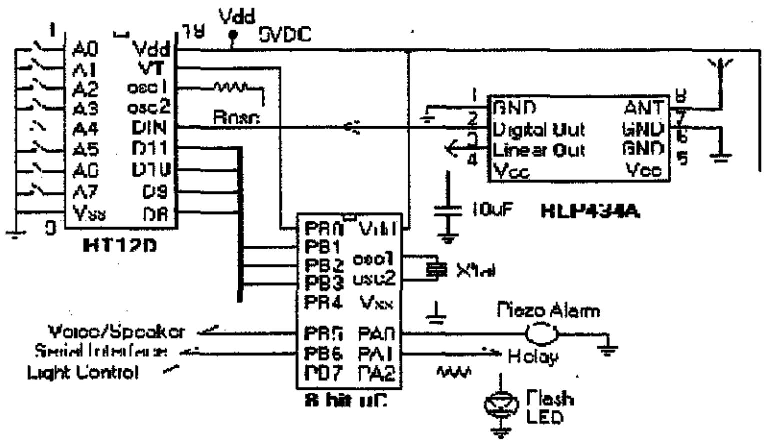
Symbol	Parameter	Conditions	Min	Typ	Max	
Vcc	Operating supply voltage		3.3	5.0V	6.0	V
Itot	Operating Current		-	4.5		mA
Vdata	Data Out	Idata = +200 uA (High)	Vcc-0.5	-	Vcc	V
		Idata = -10 uA (Low)	-	-	0.3	V

Electrical Characteristics

Characteristics	SYM	Min	Typ	Max	Unit
Operation Radio Frequency	FC		315, 418 and 433.92		MHz
Sensitivity	Pref		-110		dBm
Channel Width			+-500		Khz
Noise Equivalent BW			4		Khz
Receiver Turn On Time			5		ms
Operation Temperature	Top	-20	-	80	C
Baseboard Data Rate			4.8		KHz

Application Circuit :

Typical RF Receiver using HT12D-18DIP, a Binary 12 bit Decoder with 8 bit uC HT48RXX from Holtek Semiconductor Inc.



Laipac Technology, Inc.
55 West Beaver Creek Rd. Unit 1 Richmond Hill Ontario L4B 1K5 Canada
Tel: (905)762-1228 Fax: (905)763-1737 e-mail: info@laipac.com

LAIPAC TECH

Appendix D

Transmitter and Receiver testing range data

RANGE TESTING REPORT
by John Piskulic 6/25/00

PURPOSE:
To evaluate both range capability and noise immunity for several TX/RX pairs.

PROCEDURE:
All transmitters were powered from 12VDC and all receivers were powered from 5VDC. Three testing locations were chosen: field (open field with no structures with a 300' radius), shop1 (a commercial wood shop that had metal stud walls, tools, warehouse shelves), shop2 (home wood shop). Tests performed in shop2 were done with a minimum of 3 tools running to test for possible interference of AC motor generated RF noise. Range measurements are distances at which reception was on the border of being intermittent. Intermittent ranges could extend the apparent distance, however this was not considered for these tests. Shop 1 was limited to a maximum testable distance of 130'. If this distance was reached and reception was still good the word "MAX" appears in the table. Shop 2 had a maximum testable distance of 60'.

Transmitter	Description	Antenna
TX1	LC based	loop
TX2	TLP-315	8.9" whip
TX3	TLP-315	4" PC trace

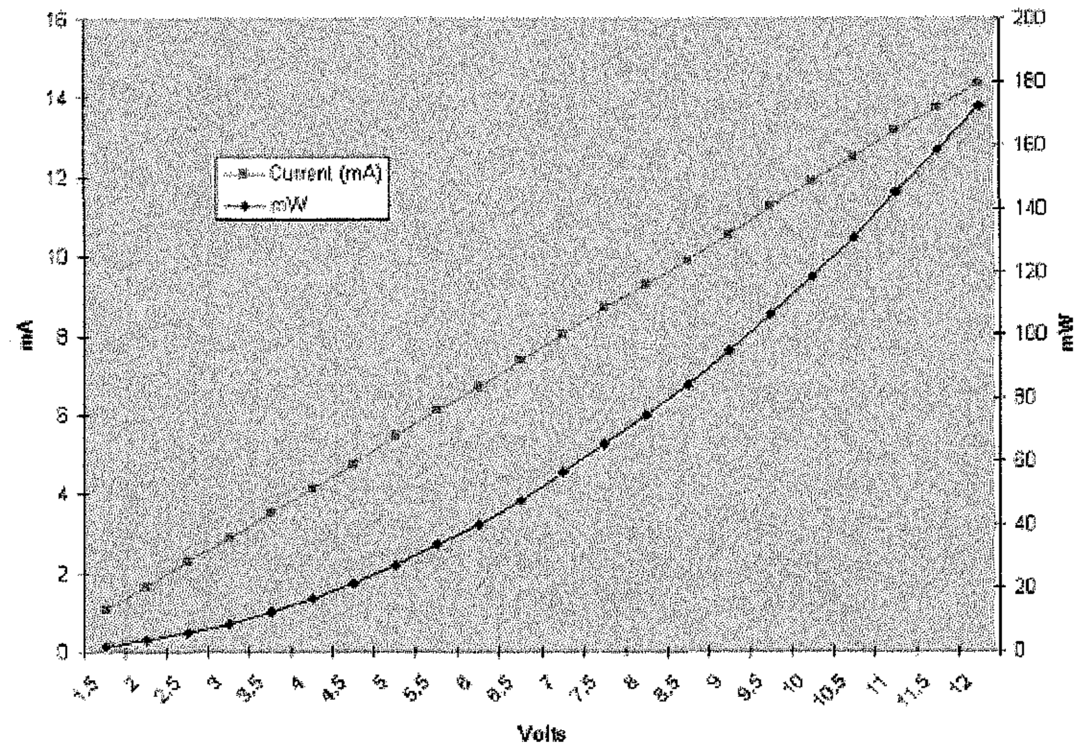
Receiver	Description	Antenna
RX1	Micrel MICRF001 eval brd	8.9" whip
RX2	RLP-315	8.9" whip
RX3	RLP-315	11' PC trace

TRANSMITTER	RECEIVER	FIELD	SHOP1	SHOP2
TX1	RX1	144	125	max
TX2	"	330	max	max
TX3	"	138	130	max
TX1	RX2	405	max	max
TX2	"	500	max	max
TX2 w/ 5.6" whip	"	415	-	-
TX2 w/ 5" whip	"	405	-	-
TX2 w/ 3" whip	"	355	-	-
TX2 no whip	"	185	-	-
TX2 no whip	RX2 w/ 5.6" whip	159	-	-
TX3	RX2	350	max	max
TX1	RX3	320	max	max
TX2	RX3	340	max	max
TX3	RX3	300	max	max

CONCLUSION:
Product range goal is 100' indoors. All combinations passed this criteria. The Micrel MICRF001 required tuning in order to achieve best range for that receiver. The TLP and RLP modules did not seem to benefit from any tuning, but simply performed better with longer antennas.

Appendix E

Transmitter power datasheet



Current (mA)
mW
mA
mW
Volts
16
14
12
10
8
6
4
2
0
200
180
160
140
120
100
80
60
40
20
0
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12

Appendix F

PIC 16F877 coding (FYP I)

```
:lude <16f877.h>
: DELAY(CLOCK=4000000) /* Using a 4 MHz clock */
ES XT,NOWDT,NOPROTECT, NOPUT, NOBROWNOUT,NOLVP

:lude <LCD.C>
:lude <key_pad.c>
:lude <string.h>
 i;
 k[3];

.input()

:har k;
cd_init();
(i=0;i<3;i++)

   delay_ms(100);
   k = get_key();
   if(k != 0)
   {
: =='C')
      {

      lcd_putc('\f');

      }
      else
      {

        lcd_putc(k);
      }
   }


:k()

      if(k[i]<=100)

        lcd_putc("very low");
        output_high(PIN_C5);

if(k[i]>100||k[i]<=200)

   lcd_putc("low");

if(k[i]>200||k[i]<=220)

   lcd_putc("normal");


1()

      get_input();
      check();
```

Appendix G

PIC 16F877 coding (FYP II)

```
:lude <16f877.h>
: DELAY (CLOCK=4000000)
ES XT,NOWDT,NOPROTECT,NOPUT,NOBROWNOUT,NOLVP

:lude <LCD.C>
:lude <string.h>

' k;

.input();

   lcd_init();
   {

    delay_ms(100);
    k = get_key();
}


:k()

    if(k<=100)
{
    lcd_putc("very low");
    output_high(PIN_C5);
}
if(k>100||k<=200)
{
lcd_putc("low");
}
if (k>200||k<=220)
{
    lcd_putc("normal");
}

1()

    get_input();
    check();
```