BACHELOR OF ENGINEERING DEGREE WITH HONOURS IN DIGITAL SYSTEMS AND COMPUTER ENGINEERING

Final Year Project Report

School of Electronic, Communication and Electrical Engineering
University of Hertfordshire

Radio Tag for Item Tracking

Report by
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May 2009

DECLARATION STATEMENT

I certify that the work submitted is my own and that any material derived or quoted from the published or unpublished work of other persons has been duly acknowledged (ref. UPR AS/C/6.1, Appendix I, Section 2 – Section on cheating and plagiarism)

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Date: 20 April 2009

ABSTRACT

This report details the designing, building and testing stages of a Radio Tag Tracking System which was undertaken as a final year project by the author of this report.

The project consisted of the development of the above said system components, namely the Radio Tag and a Base Station. Each of the components had to be developed according to a specified criterion involving size, weight, operation and communication methods. The design and development stages of each of the components have been discussed separately in this report.

During the project, an active Radio Tag was designed and developed using PIC Microcontrollers and low cost AM Transmitters. Each of the component circuits were carefully designed and tested and has been discussed in detail in relevant chapters of this report.

The Base Station was constructed to keep track of the radio tags by detecting RF signals transmitted by the Radio Tags. All the hardware and software design, development and testing stages have been discussed in detail in relevant chapters of this report.

ACKNOWLEDGEMENTS

I would like begin with thanking God Almighty for giving me strength and knowledge to finish this project. I would also like to wish my sincere gratitude to Dr. Mohammed Jamro for supervising the project and providing guidance to smooth the project work.

I would also like to thank Dr. David Lauder for answering my endless questions and correcting silly mistakes. Special thanks to Mr. John Wilmot and Mr. Ian Munro for dealing with my endless requests in the lab work.

Finally I would like to thank my family especially my mother for their continuous support and blessings during all my time in university.

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GLOSSARY

AM	Amplitude Modulation
I/O	Input/Output
MCU	Microcontroller Unit
Ofcom	Office of Communication
RF	Radio Frequency
RFID	Radio Frequency Identification
Rx	Receiver
Tx	Transmitter

1. INTRODUCTION

This report details the steps taken and the methodologies adopted in order to achieve the aims and objectives for the project. This document is intended to be read by electronic engineers or technologists and contains complete details of project research, design and testing of Radio Tags for Item Tracking.

1.1 Project Description

Radio Frequency Identification (RFID) is no longer an emerging technology in today's world. Billions of tags are manufactured and used every year around the world. These tags not only just provide an alternative to traditional barcodes as form of automatic identification, but they are also an efficient way to reduce human intervention and space required to identify, track and trace items. The most common implementation of the technology is by using a RFID Tag and a RFID reader, the two components interact with each other using Radio Frequency (RF) in order to store and remotely retrieve data [1] [2].

The key aim of this project was to develop a system to detect when an item is removed from the area where it should be kept. The system should be suitable for items such as furniture that need to be moveable within their normal area of use and cannot easily be fitted with a security cable. It could also be used for computers, whether desktop or portable. Unlike security tags used in shops this system was not to require a barrier or arch to detect when tags are moved out of the permitted area [1].

1.2 Project Objectives

In order to progress towards the aims of this project, certain objectives were highlighted and carefully planned tasks were devised. Further detailed specifications for the tracking system were then highlighted in the following points [1] [2]:-

- Design and development of a low cost, compact and battery operated Tag
- System should have a base station that can receive signals from up to 256 tags
- The distance should be adjustable in the range 1 – 20 metres.
- The alarm should include a siren and a programmable voice announcement
- There should be two types of tags, a simple transmit only tag and a more advanced transmit/receive tag.
- There should be a portable receiver that can be used to locate tags that have been removed from the permitted area by searching for the radio signals from the tag.
- In the case of a transmit/receive tag, there should be an option to send a command to the tag to emit a 'beeping' sound.

Figure 1-1 Below Illustrates a conceptual block diagram of the Tracking System that was envisaged during the feasibility study stage of the project plan. The feasibility study is discussed in detail in the second chapter of this report

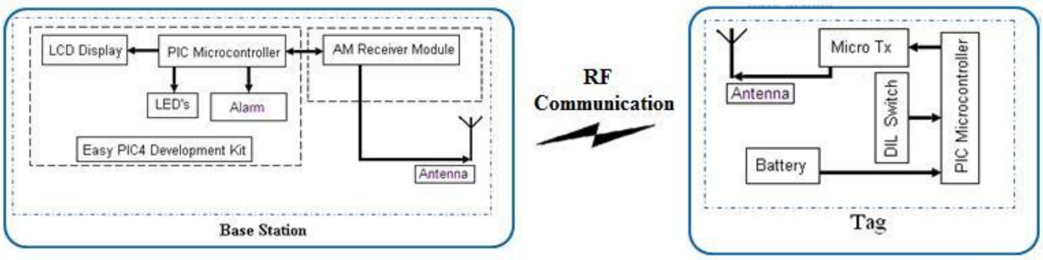


Figure 1-1 Conceptual System Block Diagram

1.3 Report Outline

The main focus of this report is to facilitate the reader with all the details of the project research, design, testing and implementation in the development of the Tag Tracking system. The different chapters in this report discuss the following project stages:-

- Chapter 2 provides a brief overview of the initial feasibility study on the research topic, the project stages and project time plan. The initial literature and hardware research done in accordance with the project time plan is also discussed in the later sub-sections of this chapter.
- Chapter 3 covers a detailed description of the project management aspects of the Radio Transmitter Tag part of the tracking system. It details the hardware design, hardware assembly, software design and testing of the Tag.
- Chapter 4 details the second part of the tracking system and details hardware and software design of the Rx (Base Station) part of the Tracking System.
- Chapter 5 provides a detailed discussion of the achieved results, modified project time plan and component costing, as well as recommendations for further work in the project area.

2. PROJCECT PLAN AND WORK STAGES

This chapter provides a brief overview of the initial research carried out on the project topic and discusses the key elements that were essential to achievement of project aims and objectives.

2.1 Feasibility Study

T he initial stages of the project required a detailed feasibility study of the project objectives, in order to highlight important aspects in the previous research in the related project field and challenges that could be anticipated in the initial phases of the project. The feasibility study also included development of a project time plan, providing an approximate time plan and work stages within the project. A copy of the final project time plans has been added in Appendix A.

Since the project was part of the development on a research project started in the previous year much of the initial research had been done by the previous year student. This included research on the RF frequency to be used and the choice of the RF components, however, none of the components, except a development board, used in the previous year were available, the project report had insufficient detail, misleading circuit schematics and the software code was insufficient for the operation of the whole tracking system. It was therefore chosen to start the project from scratch by doing the research on the RF frequency to be used and evaluation of the components used in the previous year.

2.1.1 RFID Tags

The most common implementation of RFID Technology is in RFID Tags, used for tracking and/or identifying objects, whether material or human. The Radio Frequency (RF) Tags usually consist of at least two essential parts, an integrated circuit to store and process information, RF modulation/demodulation etc. And an antenna for receiving and transmitting the radio signals. According to the number of components, the Radio Tags could then be classified as:-

Read Only: The data stored on the tag could only be read, if the tag is within the range of the reader and cannot be edited in anyway.

Read/Write Tags: The data on these tags can be edited, added to, or completely rewritten but again only if the tag is within the range of the reader.

The Tags are then further classified in the types depending on the type of power circuitry. These types include [2]:-

- Active Tags: These contain a battery that powers the microchip and allows the tag to transmit periodic signals to the reader.
- Passive Tags: These kinds rely solely on the power generated by the electromagnetic waves transmitted by the reader; the waves are absorbed by the antenna within the tag to generate current for microchip to start transmitting information. This means these tags have to be within the range of the Reader for detection, which would generally be a barrier or Arch.
- Semi-Active (or semi-passive) Tags: These contain a battery to run the circuitry of the chip, but need to draw power from electromagnetic waves in order to communicate with the reader.

The addition of battery in active tags makes them considerably expensive compared to passive tags. Their overall life time is also reduced since battery's have only finite amount of electricity in them. However, Active Tags have better application potential since they do not require any barrier or arch to detect them. It was after this initial research, it was decided to use Active Tag circuit methodology for the Radio Tags in the project. The active tags allow flexibility in design aesthetics like cost, design, size and weight (as they do not specifically need to be miniature in size).

2.1.2 Radio Frequency Bandwidth Selection

The allocation of radio spectrum in UK is regulated by the standardization organisation "Ofcom". The body defines and monitors the allocation of radio frequency bandwidths and classifies them in different applications like radio and TV broadcasting, for telecommunication operators, for defence forces, and for civilian use. Generally in order to use a classified radio frequency band, a formal permission from the governing bodies is a pre-requisite. The standardization of telecommunication equipment and network in Europe is controlled by European Telecommunication Standards Institute (ETSI) [4].

Office of Communication (Ofcom) mainly controls the standardization of RF spectrum within UK, it overlooks industries like telecommunications, broadcasting, intelligent transportation, professional and amateur radio broadcasting and etc.

Ofcom has allocated some frequency bands in the UK RF Spectrum with licence exempt classification (without licence approval). The band allocations have carefully been allocated and listen in the official RF Spectrum Allocation Table [4], and extract from the Issue 15 of the allocation table has been added into Appendix C. It was after carefully consulting this allocation table, the Radio Frequency of 433 MHz was chosen as the suitable frequency for communication for this project. The frequency band (432 – 438) is licence exempt and the frequencies in the lower end of the band have maximum radiated power of only 1 mW. The frequency was deemed suitable for application in this project because of ready availability of type approved components from manufacturers within the UK and low power radiation meant less battery usage and limited range communication.

2.2 Hardware Selection

The feasibility study also included the initial costing for the project, detailing the components that could be required to complete the project and costs for each of the components. A table detailing costs of the main components used during the project is included later in this section. A detailed component list has been added in Appendix B.

2.3 Hardware Design and Assembly

The hardware design and assembly was also divided into two stages. The first stage involved design and assembly of the Radio Tag part and the second stage involved design and assembly of the Base Station interface of the project. The selection of hardware components was based on a range factors which were essential to project aims and objectives and time plan. The selection depended on:-

- Radio Frequency Licensing – The RF frequency being used should be license exempt in UK and/or EU and the components operating at those frequencies should also be certified (by OFCOM) and have low transmission power.
- Size – Since the tags were to be used on movable items, the size of the tag was to be kept minimal with as little components as possible
- Power Consumption – The power consumption of the components was to be kept significantly low in order for tags to be operated using a standard battery over a longer period of time.
- Cost – The cost was to be a major factor in the design of the tracking system. Although active tags are expensive than conventional passive tags, the actual cost of the components was to be kept to be a minimum to relate the project to its potential market value.

The maximum budget allowed for the project by the School of Electronic, Communication and Electrical Engineering was £50, while most of the RF components had higher costs and the development board being used for the receiver side alone was approximately £80. However, the costing problem was solved by using the EasyPIC4 development board used in the previous year project. This allowed the budget money to be used to purchase the RF transmitters and receiver components from specialist manufacturers. The microcontrollers and other smaller components were sourced from within the university stores which helped in keeping the prototype development costs to minimum. A concise cost list has already been listed in section 2.2.

Post hardware design stage, the hardware assembly was carried out whilst adhering to professional circuit assembly practices and the hardware size and weight criterion.

2.4 Testing

Once the hardware design and assembly phases were successfully complete, the system was tested to ensure its performance was according to the expected criteria. The testing was done using different analysis criteria and instruments. The testing was done in conditions similar to normal operational conditions of the tags with high level of noise and distance losses.

The results were then analysed to confirm the overall system performance and chalk out any hardware and software errors.

3. Radio Tag (RF Transmitter)

The project specifications required the battery operated Tag to be able to transmit an RF beacon after specific time intervals in order to be tracked by the base station [1]. This provided certain challenges in the interface design of tag's hardware and software. Both of the design aspects, with possible solutions and final design specifications are discussed in the sections below.

During the feasibility study it was decided that the tag would consist of a microcontroller and an RF transmitter. The microcontroller would perform all the number crunching regarding tag number detection and then would transmit the tag number to an RF transmitter which would transmit the data using amplitude modulation technique.

3.1 Hardware Selection

The hardware selection for the radio tag was an important stage in the whole project time plan. Much of the research on the hardware components was done during the feasibility study stage and further literature research was carried out whilst considering different hardware characteristics and final component selection done.

The microcontroller to be used for the tag number detection was chosen to be a PIC 16F88 microcontroller and Micro Tx Transmitter from Low Power Radio Solutions was chosen as the RF transmitter. The AM (Amplitude Modulation) transmitter works at 433.92 MHz Frequency which is low power and licence exempt in UK [4] [5] [Appendix C]. The microcontroller software code was written using MikroC programming language and it was programmed using an EasyPIC4 Development Board. All the hardware components are described in detail in the later sub-sections of this chapter. A block diagram of the Radio Tag has been added below.

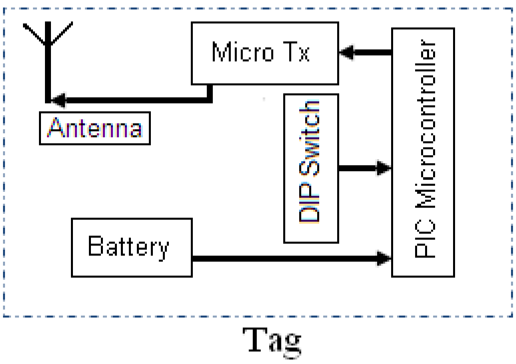


Figure 3-1 Block Diagram of the Radio Tag

3.1.1 PIC 16F88 Microcontroller

PIC 16F88 is an 18-pin, 16 Bit MCU (Micro-Controller Unit) from the Mid-Range family of the PICmicro® devices by Microchip [7]. The microcontroller was chosen as the control logic for the tag circuit because of its low cost, compact size, free development tools, and serial programming/re-programming with flash memory capabilities. The microcontroller also has some special features which were particularly useful considering the scope of the project. A pin diagram of the PIC 16F88 has been included below (also see Appendix E for relevant MCU information). The special features included [6] [7]:-

- 100,000 erase/write cycles in flash program memory
- EEPROM Data Retention:> 40 years
- In- Circuit Serial Programming™ (ICSP™) via two pins
- Extended Watchdog Timer (WDT)
- Wide operating voltage range: (2.0V to 5.5V)
- Low power consumption
- Variety of Oscillator Modes with 8 user selectable frequencies (31 KHz – 8 MHz)
- Addressable Universal Synchronous Asynchronous Receiver Transmitter (AUSART/SCI) with 9-bit address detection.

Table 1 PIC 16F88 Specifications

Parameter Name	Value	PIN Diagram
Program Memory type	Flash	
Program Memory(KB)	4 x14	
CPU Speed (MIPS)	5	
RAM Bytes	368 x 8	
Data EEPROM (bytes)	256 x 8	
Timers	2 x 18-bit, 1 x 16-bit	
ADC	7 ch, 10-bit	
Comparators	2	
Serial Comms	USART	
I/O Ports	Ports A, B	
Instruction Set	35 Instructions	
Resets	POR, BOR	
Temperature Range (C)	-40 to 125	
Operating Voltage Range (V)	2 to 5.5	
Pin Count	18	

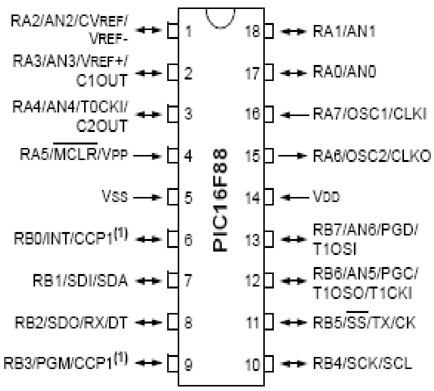


Figure 3-2 PIC 16F88 Pin Diagram [7]

3.1.2 EasyPIC4 Development Board

The EasyPIC4 development system is a development board for PIC Microcontrollers. It is designed to allow students and engineers easily explore and test the capabilities of PIC microcontrollers. The development board can be used to interface PIC microcontrollers with external circuits and a broad range of peripheral devices, allowing a user to concentrate on software development [8] [9].

Each of the components on the board is marked on the silk screen on both top and bottom sides of the board, describing connections to microcontrollers and operational modes. Since all the relevant information is printed on the board, the board is very easy to use and no additional schematics are required. Figure 3-3 illustrates the development board with its important components explained [8, 9].

The board can easily be connected to the USB port of a computer with an installed version of MikroC programming language using a USB 2.0 cable. User can insert a PIC microcontroller into its relevant socket and then program it through the USB connection using the *PICFlash2* Programming software supplied with the development board [8] [9].

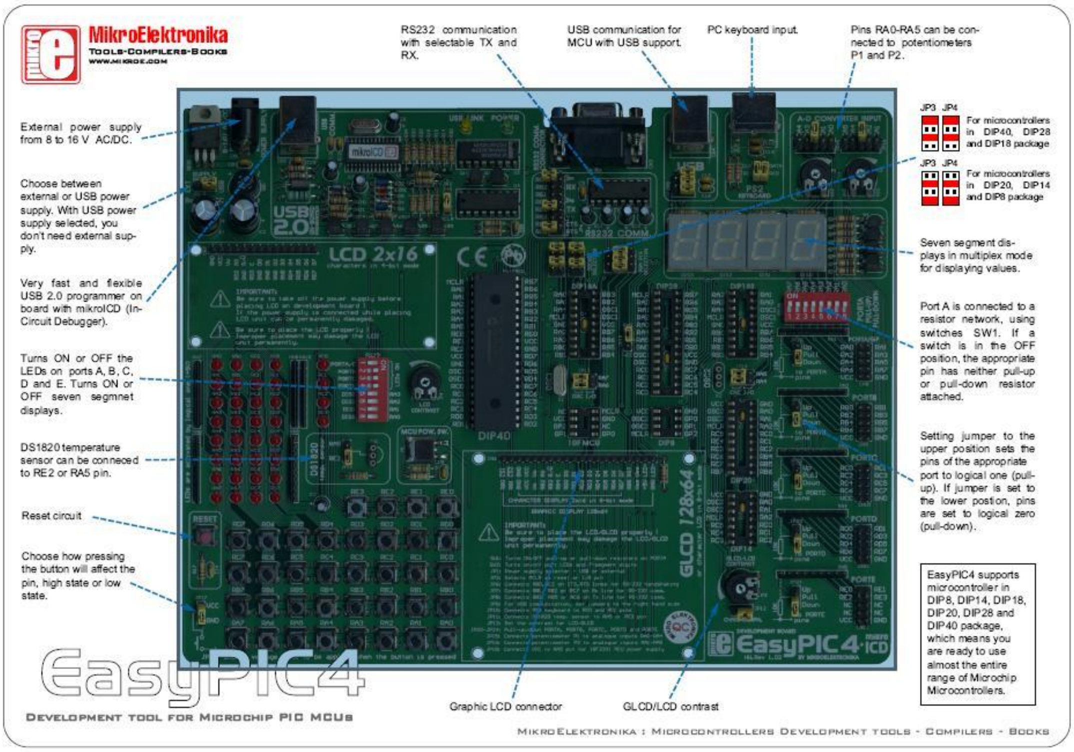


Figure 3-3 Diagram for EasyPIC4 Development Board explaining key components [8]

The EasyPIC4 development board features a number of peripheral devices and therefore in order to enable these devices before programming any PIC microcontroller, it is important to check if appropriate jumpers or switches have been properly set [8] [9]. Although the board has numerous components and peripheral devices, components relative to this project have only been explained in Appendix F. For further information about board operation, the user manual for EasyPIC4 development board should be consulted [8].

3.1.3 Micro TX Transmitter Module

Micro TX is a low cost, type approved, RF transmitter which works at UHF (Ultra High Frequency), manufactured by Low Power Radio Solutions. The module is compatible with low cost super-regenerative and AM superhet receivers. The datasheet for the module was consulted before purchasing the module to ensure it's electrical and hardware specifications were in accordance with the project aims.

The module has a sub-miniature two-pin package which makes it very useful to be applied in circuits where space is limited and the overall circuit design is compact [5]. Since one of the aims of the projects was to create a radio tag which is compact in size, the Micro TX module passed the selection criteria.

The unique design of the module allows it to be operated on any supply voltage between 2.5 and 13V, simply by changing one external resistor and it is compatible with most encoding ICs operating from 3V to 12V [5]. The transmit pin on PIC 16F88 microcontroller works at 5V DC which ensured the electrical specifications of the module were compatible with the microcontroller.

The module works at 433.845 MHz frequency and can achieve up to -6 dBm radiated power with a 90mm whip antenna, however, its best operational performance could be achieved by using a standard ¼ wave whip antenna. The antenna used with the module was therefore chosen as a ¼ wave whip antenna [16] to allow for best operational performance.

The datasheet for the module also stated that it has an operational range of up to 100 metres [5]. That ticked another of the selection criteria of tag range to be from 1 – 20 metres. Table 2 details the detailed technical specifications of the module.

Table 2 Micro Tx 433 Transmitter Absolute Maximum Ratings [5]

Parameter	**Typical**	**Units**
Frequency (UK)	433.92	MHz
Module Voltage	2.2 – 3.0	Volts
Supply voltage (RD = 680 Ohms)		
Input Current (mark)	3.0 – 4.6	mA
Input Current (space)	0	mA
Effective Radiated Power (ERP)	-6	dBm
Maximum Baud rate	1200	bps
Range (with suitable receiver)	100	Metres
Dimensions	8.5 x 7.0 x 4.2 +/- 10%	mm
Pin Pitch	5.08	mm
Operating Temperature	-10 - +40	deg. C
Storage Temperature	-40 - +85	deg. C
Matching Receiver	AM2000 Receiver	N/A

Relevant pages from the module's datasheet have been added into Appendix G. During circuit design, multiple changes were applied to the application circuits recommended in the datasheet. The changes have been discussed in later sub-sections of this chapter.

3.2 Circuit Design and Assembly

The circuit design stage for the Radio Tag was completed after detailed project research and by consulting the data sheets for the PIC microcontroller and the Micro Tx module. A number of reference books and internet sources were consulted to identify the right components for the microcontroller circuit and follow the manufacturer's guidelines. The hardware design and assembly was done to the best possible professional approach and all special care was taken to reduce costs and create an efficient hardware prototype.

Figure 3.4 below shows the final hardware circuit, the main schematic for the Radio Tag hardware is also given in Appendix H. The important components in the hardware have been labelled in the diagram below.

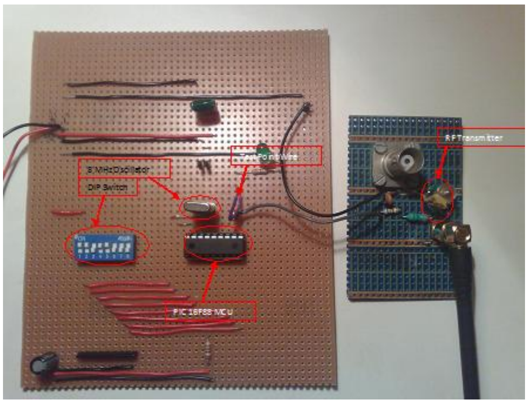


Figure 3-4 Complete Radio Tag Hardware

In order to avoid mistakes in final circuit and allow for modular testing, the circuit assembly was divided into two stages.

- Microcontroller (MCU) circuit assembly
- Micro Tx circuit assembly

Details of the circuit assembly stages have been discussed in the later sub-sections of this chapter.

3.2.1 MCU circuit Design and Assembly

The first step in power management of the circuit was to check the voltage and current usage of all the components in the circuit. The table below details the power budget for the Radio Tag circuit.

The microcontroller voltage and current consumption values were obtained from the relevant datasheets given in Appendix E. The microcontroller works with 5V DC supply and any of its input/output (I/O) ports can source or sink up to 25mA current. Therefore pin 14 (V_{DD}) pin of the microcontroller was connected to the 5V DC power supply rail. As all the electronic devices need a ground connection to work, pin 5 (V_{SS}) of the microcontroller was connected to ground (0V) rail. The ground rail was made a common ground between all the components on the circuit board.

The microcontroller has a MCLR pin (pin 4, RA5/MCLR/V_{PP}), which could be used to RESET the microcontroller so that it should start executing its program code from the beginning. Since, the project aims and objectives did not require the Tag to be reset at any time in operation; no Reset button was added to the tag circuit. However, the MCLR pin needs to be pulled up to the V_{DD} (5V) in order to allow the microcontroller to start working. But voltage spikes at the MCLR pin can cause the processor to latch-up, so rather than tying the pin directly to VDD, a series resistor of value 10 kilo-ohm was used to pull MCLR to VDD [6]. One important step during the power supply management of the circuit was to ensure decoupling of the power supply rails. Most power supplies, sometimes supply an AC signal superimposed on the DC power line, such noise signals are mostly undesirable in powered circuits [10] [11] and in RF systems, these noise signals can easily result in unwanted oscillations. A common RF decoupling technique is to feed the DC supply to each stage through a path that has high impedance at signal frequencies but low impedance at DC [12] [13]. During transition of the circuits from one state to another (and from low current requirements to high), the internal (and external) current draws inside the chip change, which produce fluctuations in the internal voltage levels of the microcontroller chip, causing it to lock up, reset or behave unpredictably in other ways. The decoupling capacitor filters the power fluctuations and provides a stable power supply for the chip [14]. Therefore, a 100uF electrolytic capacitor was connected between the all the V_{DD} pins and wired to ground, as shown in Fig 3-5 below.

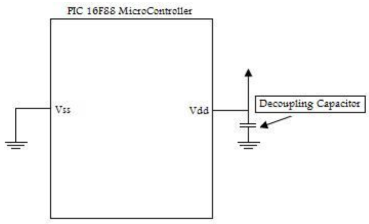


Figure 3-5 Decoupling a PIC 16F88 MCU

The circuit design involved connecting an 8 pin DIP switch (see figure 3-6 below) to the microcontroller. As described in Section 2.1 the DIP switch is used to input the Tag serial number into the microcontroller.

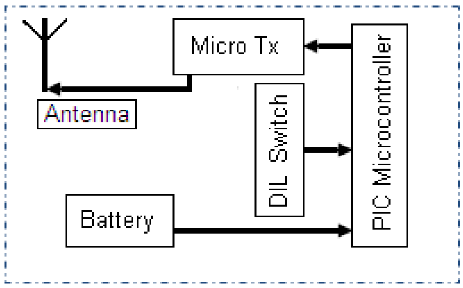


Figure 3-6 Radio Tag Block Diagram

Since the microcontroller would read the DIP switches as individual binary numbers, the 8 Switches could provide us with a possible $2^8 - 1 = 255$ different tag numbers. A pin map of the DIP switch with the microcontroller ports and their equivalent decimal value is given in figure 3-7 below.

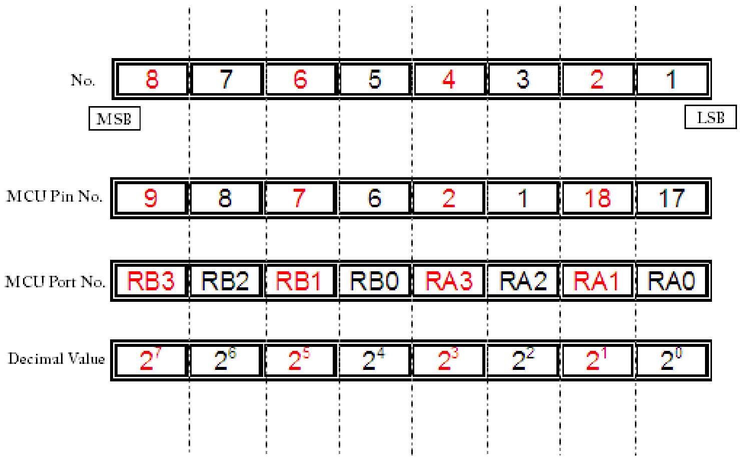


Figure 3-7 Pin Map for the Tag No using 8 Pin DIP Switch

The DIP switch is connected to RA0, RA1, RA2, RA3 and RB0, RB1, RB2, RB3 pins of the microcontroller. The input of the DIP switch is connected in parallel to the 5V Power Supply to the microcontroller, providing 5V to each of the switches. If any of the 8 switches is turned to

ON position then the 5V volts are applied to the corresponding pin of the microcontroller. The above stated pins on the microcontroller were declared as inputs in the microcontroller's program code, which allowed the tag serial number to be read in to the program (see section 3.5.1 for examples of Tag serial numbers). If any of the switches were turned off in any particular tag serial number, the MCU pins connected to these switches would be left floating. This has an undesirable effect of stray micro-volts being fed into the MCU pins and a wrong resultant tag number being read into the MCU. In order to eliminate this effect a 4.7 kilo-ohm pull-down resistor was connected to each of the microcontroller pins and ground (0V). Connection of the resistor with MCU means if any of the DIP switches are off then the corresponding MCU pin is pulled down to ground and a constant 0V is read at that pin.

Adding individual resistors to the pins meant extra wiring connections from the microcontroller to the ground. To avoid cluttering the circuit board with multiple resistors, an 8 pin 4K7 network resistor [15] was used.

Figure 3-8 A Typical SIL Network Resistor [15]

The network resistor assists in reducing the number of components and soldering pins in the circuit. The 8 pins were therefore connected in parallel with MCU's Pins and the common pin was connected to the ground (0V) connection.

All microcontrollers need a clock signal to work with. The PIC 16F88 microcontroller has internal oscillator but for better performance an external oscillator could be used with the microcontroller. To achieve better and accurate performance, an external 8 MHz crystal oscillator was connected to the RA7/OSC1 and RA6/OSC2 pins of the microcontroller. As stated in the product datasheet, two 22 pF capacitors were connected between the oscillator pins (one each on each pin of the oscillator) and the Ground (0V) to allow for a basic start-up time and stable oscillator operation [6].

The MCU circuit was first assembled on a prototyping breadboard. The prototype was then used to test the overall operation and stability of circuit design including the DIP switch and the oscillator operation. A picture of the prototype MCU circuit is added below in Figure 3-9.

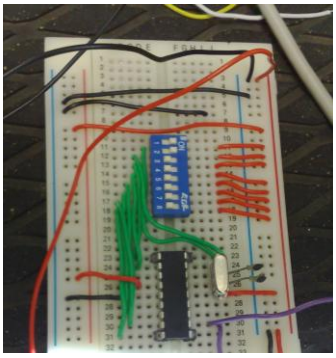


Figure 3-9 Prototype MCU circuit with DIP switch and PIC 16F88

Once satisfied, the microcontroller circuit was then transferred over to a Vero board (Appendix L). All of the circuit components were through-hole components and therefore no problem was encountered in placing any of the components on to the board. An 18 pin DIP socket was soldered in place of the microcontroller, and the microcontroller was then placed in the socket. This was done to assist in the programming phase of the project, where microcontroller could easily be taken out of its socket and re-programmed with a new version of program/software code. The components were carefully placed on to the board and their connection tracks were checked before soldering all of the components to the Vero board. All the tracks between the adjacent DIP switch pins and DIP socket pins were carefully cut using a track cutter. This was done to avoid any short circuit between the sensitive components especially the microcontroller and the oscillator.

After the soldering stage, all the connections were checked under a 7x microscope to check for any dry joints or bridged connections. A multi meter was then used to check for any short circuits. Any resulting errors were corrected and soldering was completed and given a thorough check again before powering up the MCU circuit for the first time.

Since the circuit was built to work as a prototype, standard 5V power supplies in the labs were used to power up the circuit, this avoided adding extra battery component costs to the overall project budget. Two wires (red for +5V and black for 0V GND) were soldered onto the power supply rails on the Vero Board which were then connected to the laboratory power supply to power up the circuit.

During the hardware testing stages, an LED was connected in series with the data output pin (RB5, pin 11) of the microcontroller. Since the I/O ports of the MCU can only source up to 25 mA current and the Micro Tx transmitter module draws 4mA current, a 330 ohm resistor was also added in series between the LED and the MCU pin to limit the current being drawn by the LED. The LED was added to indicate if the MCU is powered up and is transmitting any data to the RF transmitter. The final MCU hardware circuit is shown in Figure 3-10 below.

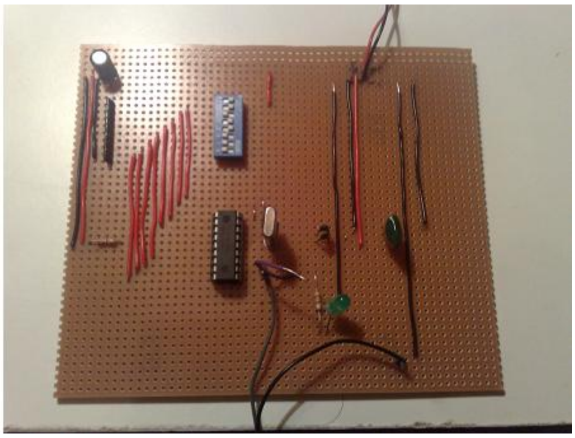


Figure 3-10 Final PIC MCU Circuit on Vero Board

3.2.2 Micro Tx Transmitter circuit Design and Assembly

The main task in designing the Micro Tx transmitter circuit was identifying the right application circuit in its datasheet (Appendix G) and then identifying the right components according to the MCU circuit specifications. The right application circuit diagram from the relevant data sheet [5] is given in the Figure 3.11 below.

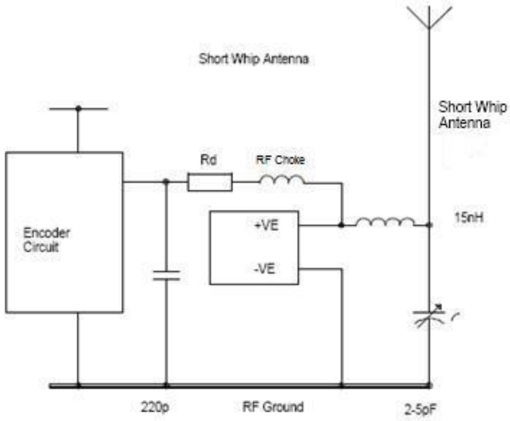


Figure 3-11 Application circuit diagram for Micro Tx Module [5]

As explained earlier in section 3.1.3, the Tx pin (RB5) of the PIC 16F88 MCU provides a 5V supply voltage when its transmitting data and the Micro TX module could work on any voltage between 2.5 V and 13V. The resistor value table provided in the datasheet was used to identify the value of the series Rd shown in the circuit diagram above. The voltage range was chosen as 4.2V to 6.1V and hence the Rd value is 680 ohm. The recommended value of RF choke in the data sheet is 100 uH. The complete schematic of the Radio Tag including the Micro TX transmitter circuit has been added in Appendix H.

Table 3 Bill of Materials for Micro Tx Transmitter Circuit

Item #	Description	Quantity
1	Resistor, 680 Ohm	1
2	RF Choke, 100 uH	1
3	Capacitor 220 pF	1
4	Inductor, 15 nH	1
5	Variable Capacitor, 2 – 5 pF	1
6	¼ Wave Whip Antenna	1

An important aspect to note is identifying the polarity of the transmitter module. The package dimension diagram in the datasheet shows that there is a small hole or circle on the +ve pin. In actual, although there is a small circle visible just above one of the pins of the module, the actual +ve pin is marked with a red line on that side of the module.

The antenna used with the module is a ¼ wave whip antenna which was recommended in the product datasheet for best performance. The whip antenna is a monopole antenna, with a single driven element and a ground plane. The antenna is stiff but flexible wire mounted, and their length determines their wavelength, although it could be shortened with a loading coil anywhere along the antenna. Whips are generally a fraction of their actual operating wavelength, with half-wave and quarter wave whips being more common [16]. They are particularly useful in situations where flexibility is an important issue and the antenna shouldn't break when struck. The characteristics of antenna were also feasible for the application criteria of the radio tags.

In order to achieve low impedance return path for power and signals at all frequencies in RF system, an effective ground plane is always required. In ideal RF systems, all pointes connected to the ground must be at the same potential, but in active RF systems, it is not deemed an easy task due to presence of high frequencies. Common PCB's have effective inductance at their ground tracks. To overcome the effects of inductance problem, a continuous conductive "ground plane" board can be used.

In a ground plane prototype board, one side is dedicated to running all of the necessary interconnections between components. The other side is a continuous copper layer and all ground connections are made to the ground plane. In the case of through-hole mounted components, a plated-through hole is normally provided whereas for surface-mounted components or prototype construction, components can be soldered directly to the ground plane [12] [13]. To achieve the best possible performance and reliability in RF system, the transmitter circuit was assembled on a Colander Vero board. The Vero board is made of epoxy glass with a colander ground plane for maximum screening (see Appendix L). Since the circuit is an Ultra High Frequency (UHF) RF system, all the components were soldered as close to each other as possible to avoid unwanted oscillations and impedance from the circuit board.

A SMA connector was mounted on top of the circuit board to fix the antenna vertically down and the connection between the antenna and the inductor (in series with the module) was established by soldering the connector pin onto the circuit board. The SMA connector legs were too big in diameter for the through holes on the board, so the holes were enlarged by drilling through them. The connector legs were then soldered onto the ground plane to ensure good grounding. A picture of the completed circuit for the Micro TX Transmitter module is given in the figure below.

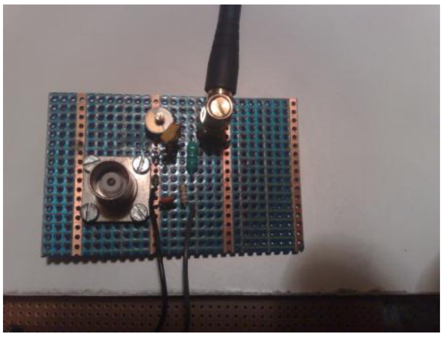


Figure 3-12 Complete Circuit for the Micro TX Transmitter Module

3.2.3 Complete Tag Assembly

The task of complete tag assembly was completed by connecting the two circuit boards (MCU circuit board and Micro TX circuit board) together by using electrical wires. One wire was connected between the Tx pin (RB5) of the microcontroller and the resistor Rd on the module circuit board. The other wire was used to connect the ground plane on the transmitter circuit board to the common ground on the MCU circuit board.

A picture of the final Tag Hardware has already been added in Figure 3-4.

3.3 Microcontroller Software Code

The software program for the PIC 16F88 used in Radio Tag was written using mikroC programming software which is a well known software development tool for PIC microcontrollers. The compiler has been designed to facilitate users with easiest solutions to develop embedded applications without compromising performance or control [18] [19].

Different versions of software code were created to ensure effective usage of the speed and memory space of the microcontroller. The two most noteworthy versions of the software code including the final version have been discussed in the following subsections.

3.3.1 MikroC Compiler & Software

mikroC has a variety of options that allows its users to quickly create and test complex applications. The important features include [18]

- Write C code using highly advanced Code Editor
- Use the included MikroC libraries to speed up the development, data acquisition, conversions, displays communications etc.

- Monitor the program structure, variables, and functions in the Code Explorer. Generate commented, human-readable assembly, and standard HEX files compatible with all programmers.
- Inspect program flow and debug executable logic with integrated Debugger. Get detailed reports and graphs on code statistics, assembly listing, and calling tree.
- Availability of plenty of examples to expand, develop and use as building bricks in projects.

One of the other features of the MikroC is its integrated tools. One tool of special interest in relation to this project is the USART Terminal, the USART (Universal Synchronous Asynchronous Receiver Transmitter) communication terminal for RS232 communication [18]. The tool was used during the testing stages of the project to verify the output of the microcontroller used in the Radio Tag. Further information about the MikroC compiler and development tool could be obtained by referring to its user manual and documentation [18] [19].

Although the University had a full licence of the MikroC software, much of the software code was developed using the demo version of the software. The demo version has almost all the operational features of the full version, except the usage of some specialist libraries and the code length is limited to 1000 lines. The limited usage of libraries resulted in some problems during the software development which is explained in the later subsections, however, the code length of 1000 lines was never an issue for this project as much of the code was only 100 or less lines long.

The first step towards writing the software code for the PIC 16F88 microcontroller for radio tag was to create a basic data flow chart. The aim for developing the flow chart was to show the flow of information within the micro-controller, modularize the code and makes the code understandable. The Basic data flow diagram for the Radio Tag part of the system has been added into Appendix G.

3.3.2 Initial Software Code

The PIC microcontroller provides the feature of reading individual port pins in the software code (instead of reading the whole 8 pins of the port). Since the 8 pins of the DIP switch were connected to individual microcontroller pins, the binary values of those pins were read into a variable array. The main aim in software development was to read in that binary number correctly into the microcontroller and then transmitted periodically on the USART port (RB5/Tx Pin). The USART port however transmits data using hexadecimal values. If the array holding the tag number was to be transmitted using USART the individual elements would have been considered individual numbers and thus a wrong set of values would've been transmitted through the USART.

One of the possible approaches towards transmitting the tag number correctly was to convert the individual binary bits in the array to a decimal number and then sending that decimal number (or its hex value) through USART. But the limitations in the demo version of the MikroC software didn't allow the user of the *power()* function [18] to convert individual binary numbers to their corresponding decimal number. As a solution to the demo version limitations, a binary to decimal conversion function along with a binary power converter function were written within the software code. This slightly increased the memory usage and function call number in the overall program, but since the overall program execution was very efficient, addition of these extra functions did not have any noticeable effect on operation of the microcontroller. The initial software code has been added in the figures below. The code is distributed into three figures to assist in explanation of the functionality of the code. The complete software code has been added into Appendix K.

```
C:\Users\RizMeistro\Tag Tx\Tag_Tx.c                                14/04/2009 02:39:25

 1: /*******************************************************************************
 2: Radio Tag For Item Tracking
 3: Transmitter Side Code
 4: Name: Ramiz Ahmed (DSCE 4)
 5: Supervisor: Mohammed Jamro
 6: BEng Digital Systems & Computer Engineering
 7: Version: Version 2
 8: *******************************************************************************/
 9:
10: float dt;
11: float t;
12: unsigned short TagNo[8]; // 8-Bit Long Array, storeS Tag No read from DIP Switch
13: int i;
14: int j;                       // Integer i to be used in for loop
15: int temp1;
16: int temp2;
17: int dec_TagNo;           // Decimal Value of Tag No on DIP Switch
18:
19:
20: int b2dec();             // Function to Convert Binary to Decimal
21: int Power(int i);        // Function to calculate Decimal Value of Each Binary No.
22:
```

Figure 3-13 Initial Radio Tag Software Code Version 2 (1 of 3)

Figure 3-13above shows the first few lines of the version 2 of the initial software code. Much of the code is self-explanatory and detailed comments have been used to identify the functions of each command line. Lines 1-6 are commented lines providing details about the code file, including the project title, code type, programmers name and version of the software code.

Lines 10 - 17 declare different global variables being used in the program. The code line:-

unsigned short TagNo [8];

is the declaration of the array TagNo with length of 8 to store the 8 binary numbers being read into the code. Since the values being read are only binary (either 1 or 0) the data type of the variable is declared as unsigned short variable array.

Lines 20 and 21 declare the two functions created later in the software to do the binary to decimal conversion mentioned in the beginning of this section.

```
23: /*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*/
24: /*~*~*~*~*~*~*~*~*~*~*~*~*~**~*~* Power Function*~*~*~*~*~*~*~*~*+*~*~*~*~*~*~*~*/
25: /*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*/
26: int Power(int temp2)
27: {
28: int Result = 1;
29: if (temp2 == 0) {return 1;}
30: else
31: {
32: for (i=1;i<=temp2;i++)
33: {
34: Result = Result * 2;
35: }
36: return Result;
37: }
38:  }
39: /*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*/
40: /*~*~*~*~*~*~*~*~*~*~*~ Function to Convert Binary To Decimal ~*~*~*~*~*~*~*~*/
41: /*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*/
42: int b2dec() {
43: int decimal = 0;
44:  for(temp1=0;temp1<8;temp1++)
45:  {
46:     if (TagNo[temp1] ==1)
47:        {decimal = decimal + Power(temp1); }
48:  }
49:   return decimal;
50: }
51: /*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*~*/
52: void main() {
53: dec_TagNo =0;              // Initialize Tag No as Zero
54:
55: ANSEL = 0x00;
56: INTCON = 0x00;
57: PORTA=0x00;                // Initiliaze Port A at Zero Logic Value
58: PORTB=0x00;                // Initiliaze Port B at Zero Logic Value
59: TRISA = 0b11111111;        // Declare Port A as Input
60: TRISB = 0b11011111;        // Declare Port B as Input Expcept RB5 (output)
61:
62:
```

Figure 3-14 Initial Radio Tag Software Code Version 2 (2 of 3)

Figure 3.14 above shows the part of the software code where the power and conversion functions are defined.

Lines 24 to 38 (see figure) form the function where the power function is defined. The function takes one integer input variable and returns an integer output. The main operation of the function is to convert the binary number in to its corresponding value. The bits in any binary number ascend in the order of the power of binary numbers e.g. 2^0, 2^1, 2^2, 2^3 etc. in order to convert a binary number to decimal number it is important to convert the binary number at that bit correctly to its decimal value (value of 2 raised to its power, the power is the position of the bit in the whole binary number).

The first part of the function is a conditional 'if' statement which checks whether the input given to it is zero or not. If it is zero (i.e. 2^0) then the function returns the value of 1 to its calling function by default.

```
if (temp2 == 0) {return 1;}
```

However, if the input value is not integer ‘0’ then the ‘if’ statement is false and the program goes to the ‘else’ part of the conditional statement. The else part contains a FOR loop which starts from 1 and terminates at the value input to the function “temp2”.

```
for (i=1;i<=temp2;i++)
{
Result = Result * 2;
}
return Result;
```

The loop iterates the code in which it multiplies the value stored in the ‘Result’ variable by 2 and then stores the resultant value back to ‘Result’ variable. The value is then used in the next iteration and so on until the loop terminates. After the first iteration, the ‘Result’ variable has value of ‘2’ in it. As shown in example below, in the successive iterations this has an effect of raising the number 2 to its power (the number of iteration in the loop).

Loop 1:	Result = Result * 2 =	1 * 2	= 2	$\approx 2^0$
Loop 2:	Result = Result * 2 =	2 * 2	= 4	$\approx 2^1$
Loop 3:	Result = Result * 2 =	4 * 2	= 8	$\approx 2^2$
Loop 4:	Result = Result * 2 =	8 * 2	= 16	$\approx 2^3$
Loop 5:	Result = Result * 2 =	16 * 2	= 32	$\approx 2^4$

After the loop terminates, the value stored in the Result variable is then returned to calling function.

Lines 42 till 50 form part of the Binary to Decimal conversion *b2dec()* function. This function does not take any inputs but returns an integer value stored in its ‘decimal’ variable.

```
for(temp1=0;temp1<8;temp1++)
 {
   if (TagNo[temp1] ==1)
     {decimal = decimal + Power(temp1); }
 }
```

The main part of this function is a FOR loop. The FOR loop starts at zero and terminates at the value of 7. The reason for the 8 loops is the fact that there are 8 switches connected to the microcontroller and the array storing the values of those pins is 8 values long. The code in the loop picks a value from the ‘*TagNo []*’ array (the value corresponds to the loop iteration), and does a conditional check on the value. If the value in the array is equal to zero (switch at that pin is OFF i.e. logical zero input), the code skips the rest of the code and goes to the next loop. However, if the value is 1 (switch at the pin is ON i.e. logical 1 input), then the next line in the code calls the *power()* function, the input to the function is the iteration number in the

FOR loop. The returned value from the *power()* function is added to the current value of the 'decimal' variable and the resultant value is stored back to the 'decimal' variable. All of these operations are done in one code line i.e.

```
decimal = decimal + Power(temp1);
```

After termination of the FOR loop, the final value in the 'decimal' is returned to the calling function.

The main body of the program starts at line 52. Lines 53 – 60 contain the code which configures the registers, ports and interrupts in the PIC microcontroller. The following lines

```
ANSEL = 0x00;
INTCON = 0x00;
```

Disable the analogue-to-digital converter and interrupts within the PIC MCU as they are not necessary in the operation of MCU in this particular application. The next lines configure the pins in PORTA and PORTB as inputs/outputs individually and initialize them at logical value zero.

```
PORTA=0x00;          // Initialize Port A at Zero Logic Value
PORTB=0x00;          // Initialize Port B at Zero Logic Value
TRISA = 0b11111111;  // Declare Port A as Input
TRISB = 0b11011111;  // Declare Port B as Input Except RB5 (output)
```

All the pins in Port A are declared as inputs and all the pins in Port B except port RB5 are declared as input as well. RB5 in Port B is declared as output since this is the RB5/Tx pin of the MCU.

Following the port declaration is a FOR loop at lines 63 – 66 (see figure below). The FOR loop starts at zero and terminates at value 7. The purpose of the FOR loop is to initialize all the values in the *TagNo[]* array to zero. This is necessary because otherwise the compiler would store random values in the array and this could result in unexpected code behaviour or wrong Tag serial number during program execution. During each iteration, the following line stores zero at that corresponding value of the array:-

```
TagNo[j]=0;          // Assign 0 Value in all values of TagNo Array
```

Figure 3-15 below illustrates the last part of the version 2 of the initial software code.

```
63: for(j=0;j<=7;j++)
64: {
65: TagNo[j]=0;                  // Assign 0 Value in all values of TagNo Array
66: }
67:
68: TagNo[0]= PORTA.F0;          // Assign 1st Dip Switch to Port A Pin0
69: TagNo[1]= PORTA.F1;          // Assign 2nd Dip Switch to Port A Pin1
70: TagNo[2]= PORTA.F2;          // Assign 3rd Dip Switch to Port A Pin2
71: TagNo[3]= PORTA.F3;          // Assign 4th Dip Switch to Port A Pin3
72: TagNo[4]= PORTB.F0;          // Assign 5th Dip Switch to Port B Pin0
73: TagNo[5]= PORTB.F1;          // Assign 6th Dip Switch to Port B Pin1
74: TagNo[6]= PORTB.F2;          // Assign 7th Dip Switch to Port B Pin2
75: TagNo[7]= PORTB.F3;          // Assign 8th Dip Switch to Port B Pin3
76:
77: USART_init(1200);            // Initialize USART@baud rate of Micro Tx (1200 bps)
78:
79: dt = 500;
80: t = dt/2 + (rand()%100); // Create a Variable Array
81: dec_TagNo = b2dec();       // Conver Binary TagNO to Decimal Tag No
82:
83:
84: if (dec_TagNo > 0)         // Condition - TagNo =0 Not Transmitted (omitted)
85: {
86: while(1)
87: {
88: USART Write(dec_TagNo);    // Write Decimal TagNo on USART (RB5 Pin)
89: vdelay_ms(t);
90: }
91: }
92: }
```

Figure 3-15 Initial Radio Tag Software Code Version 2 (3 of 3)

The next part of the code (lines 68 – 75) maps the individual pins of Port A and port B to their corresponding values of *TagNo* array, and the values are read into the array. A pin map is already given in Figure 3-7 (Section 3.2.1).

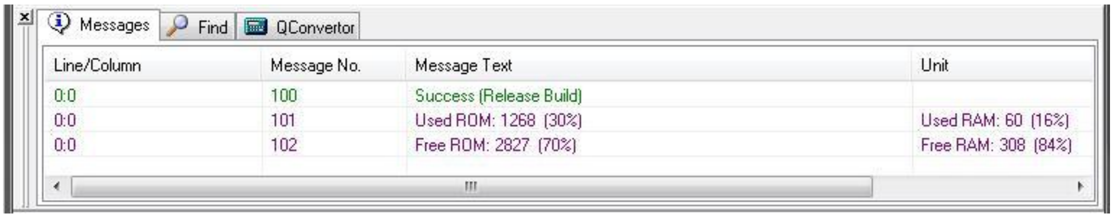
An important aspect in using USART data transmission is to initialize the USART port in the beginning of the main program body. The USART is initialized at 1200 baud rate, no parity bit, no stop bits by writing the following command at line 77. The baud rate of 1200 bps is used to match the data rate with the transmission data rate of the Micro TX Transmitter module (see section 3.1.3).

```
USART_init(1200);        // Initialize USART@baud rate of Micro Tx (1200 bps)
```

Code line 80 is used to store variable delay value in variable 't'. The variable delay value is created by adding a modulus "%" of a pseudo random number generated by a library function "*rand()*" in the software to the predefined time value which in this case is 'dt/2 = 250ms'. The *rand()* function generates a returns a pseudo-random number between 0 – 32767. However, by taking a modulus of the random by "dt = 500", the value of the random number is limited to 0 – 500 and therefore the final random time delay is always in between 250ms – 750ms.

Line 81 stores the decimal value of the tag serial number by calling the *b2dec()* function. The next line in the code does a conditional check on the decimal value of Tag No. Although in practical cases there will not be a radio tag with serial number '0', this conditional check was added for exceptional cases and for software testing purposes. If the Tag number is zero the program goes back into a loop. However if the tag number is greater than zero then the tag number is transmitter through the USART port using *USART_write()* command. Following the write command, there is a variable delay in milliseconds before the program goes into another loop. The variable delay is used as an anti-collision technique to avoid signal collisions when multiple tags are transmitting to the same base station simultaneously. Much of the anti-collision technique is discussed in the 'Testing' part of this chapter.

The EasyPIC4 board mentioned in 3.1.2 has on-board *PICFlash2* Programming software which was used to program the PIC microcontroller. The microcontroller was placed into its appropriate 18 way DIP socket and then the board was connected to the computer using a USB 2.0 cable (provided with the board) and the *Build* + *Program* option in the mikroC software environment was used to generate a HEX file and program the MCU. The memory usage statistics for the microcontroller are shown in the figure below:-



Line/Column	Message No.	Message Text	Unit
0:0	100	Success (Release Build)	
0:0	101	Used ROM: 1268 (30%)	Used RAM: 60 (16%)
0:0	102	Free ROM: 2827 (70%)	Free RAM: 308 (84%)

Figure 3-16 Memory Usage Statistics for Initial Software Code Version 2

Since the all microcontrollers and electronic boards are sensitive to static charge, the board was placed on an anti-static mat and anti-static bands were used while inserting/removing the MCU from the board. After programming, the MCU was placed into its circuit socket and the operation of the code was tested which is explained in 'Testing' part of this chapter.

3.3.3 Final Software Code

After conducting further research in possible approaches to reading the tag number from DIP switch the final code version was created. Instead of using an array to read in the tag number and then converting the binary value to decimal values a simple Bit Masking approach was applied in the code. This reduced the code length from 92 lines to just 35 lines. The new code does not require any binary to decimal conversion and there are no function declarations. The complete source code has been added into Appendix K. The final code has no difference in the microcontroller configuration and the variable delay. The only difference is the way tag serial number is read into the system. The command used to read the serial number into the program memory is

```
TagNo = (PORTB << 4) | (PORTA & 0x0f);
```

The variable used to store the tag number is declared as a character data type. In the code line above the data read in three stages. In the first stage the data read from Port B is arithmetically shifted 4 places to the left. In the second part the data read from Port A is used to do a logical and with 0x0F (binary 00001111). Then in the last part the result from first stage is used to do a logical OR with the result from the second stage. The table below gives a few examples to further highlight the bit masking methodology used.

Actual Tag Number	**Port B input**	**Port B << 4**	**Port A input**	**Port A & 0x0F**	**(Port B << 4) OR (Port A & 0x0F)**	**Tag No In Hex**
2	0000 0000	0000 0000	0000 0010	0000 0010	0000 0010	0x02
15	0000 0000	0000 0000	0000 1111	0000 1111	0000 1111	0x0F
63	0000 0011	0011 0000	0000 1111	0000 1111	0011 1111	0x3F
210	0000 1101	1101 0000	0000 0010	0000 0010	1101 0010	0xD2

In order to avoid the possibility of collision between transmissions of short bursts of data being transmitted by different tags, the software code was modified to change the random time delay between 250ms to 750ms. The *rand()* function has been explained in detail in section 3.3.2.

As detailed in section 3.5.1, the software was tested for its accuracy using multiple testing techniques and then the microcontroller was programmed with the final software code.

3.4 Testing

Much of the initial Tag hardware testing was done during the circuit assembly phase of the project. The same was applied to the software code development phase but some amount of time in the project time plan was also dedicated to the final testing of combined Radio Tag hardware and software. The major testing phase of the Radio Tag was therefore divided into two phases which are described in the following sub-sections.

3.5.1 Software Testing

The software testing was performed by using the RS232 Communication Port on the EasyPIC4 Development Board. The development board also has push button switches for each of the pins on the board which could be used to apply 5v DC to any of the port pins [8] (also see Appendix F). The MCU was placed in the 18 way socket on the board and the RS232 port on the board was connected to the serial port on the PC using a standard serial cable. The USART Terminal tool in the MikroC programming software was used to test different outputs of the software.

After connecting the serial cable to the PC and setting up the USART terminal tool at the correct baud rate and COM port, the Development board was powered up and then the push button switches were used to test pre calculated tag numbers. Different combinations of push buttons were pressed to check for expected Tag Number. The process was repeated for multiple tag numbers until the results were deemed satisfactory. The table below shows different switch combinations and expected Tag numbers in decimal and hexadecimal. Figure 3-17 shows a screenshot of the USART Terminal window when different button combinations were pressed.

Table 4 Examples of Tag Numbers according to DIP Switch Orientation

DIP Switch Orientation								Decimal Tag #	Hexadecimal Tag #
8	**7**	**6**	**5**	**4**	**3**	**2**	**1**		
0	0	0	0	0	0	1	0	2	0X02
0	0	0	1	0	0	0	0	16	0x10
1	0	0	1	1	0	1	0	154	0x9A
0	0	0	1	1	0	0	0	24	0X18

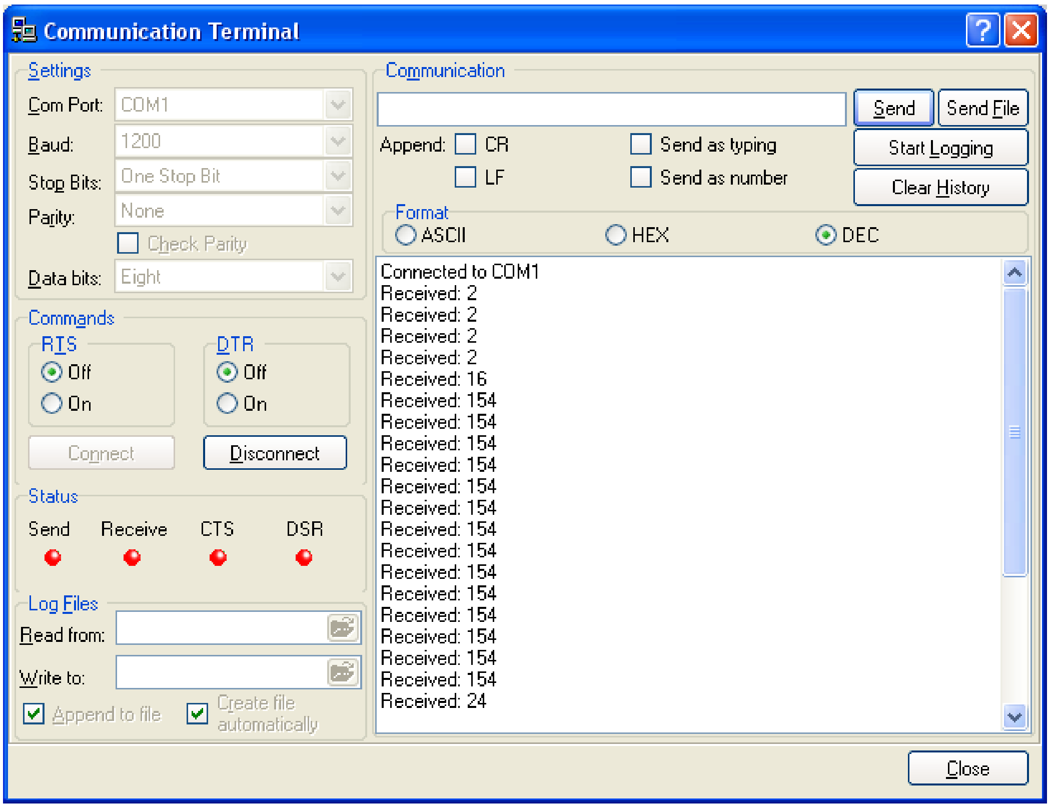


Figure 3-17 USART Terminal Window with Tag Serial# Being Transmitted

During the testing it was observed that in initial software code the DIP switches had to be put in right positions for expected serial number before powering up the circuit. If the tag serial number was to be changed, the MCU had to be reset. The final software code was restructured to eliminate this effect and the command lines reading the tag serial number were put inside the *While(1)* loop. This allowed the tag number to be changed without resetting the MCU circuit.

One of the features in the software was that the MCU would stop transmitting if all the switches are off or the tag serial number is zero ('0'). The test confirmed that MCU did not transmit any serial number when the Tag number was zero. The figure also confirms that the software was working as expected. A separate screenshot of another test session has also been added into Appendix J.

3.5.2 Hardware Testing

The hardware testing for the radio tag was performed after completing the software testing phase of the project. The MCU hardware was tested using a digital multi-meter and an oscilloscope connected to a computer to capture screenshots of the waveform outputs on the oscilloscope screen.

During circuit assembly all the component connections were thoroughly checked and any short-circuits due to poor soldering and Vero board tracks were removed before powering up the circuit for the first time. Once powered up the voltage level at all the inputs to the MCU and DIP switches were checked using the voltmeter.

The first step in MCU hardware testing was to verify the stable operation of the external oscillator. The circuit was powered up and a 1x probe as used to connect the RA7/OSC1 pin of the MCU to the oscillator. The oscilloscope settings were adjusted to display the right sinusoidal waveform and then measurements were taken to ensure the clock is operating at the right frequency of 8 MHz and its operation is stable. Figure 3-18 below shows the clock signal observed at the oscilloscope and the measurement of the clock frequency.

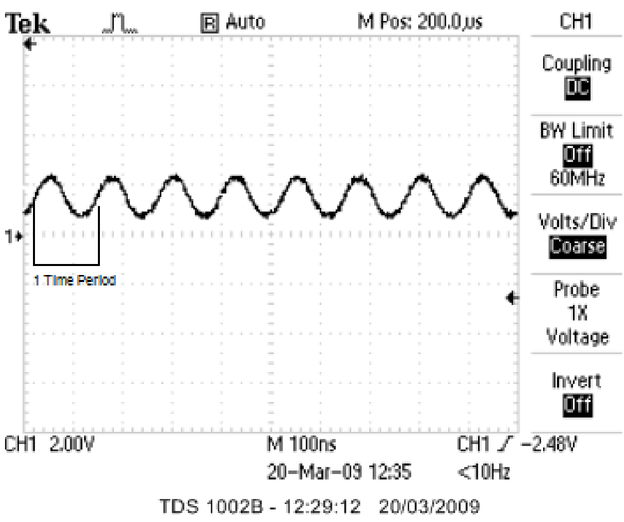


Figure 3-18 Oscillator Output Waveform @ 8 MHz

The time division settings were set to 100ns per square box. So each measurement unit in the box is 20ns. As it can be seen from the figure, one time period takes 6.5 measurement units. Theoretically, a Time Period 'T' of the 8 MHz Clock should be:

$$1 / F = 1/ (8 \times 10^6) = 125 \text{ ns}$$

If we consider the readings from the oscilloscope in the figure above

$$20\text{ns} \times 6.5 = 125 \text{ ns}$$

Which confirms the oscillator is operating at correct clock speed. The smooth waveform also suggests that oscilloscope operation is also stable.

The next step was to monitor the output from the Tx (RB5) pin on the MCU. Again the oscilloscope was used to observe the binary output signal from the MCU. The figure below shows the output waveform when the tag serial number was set to # 15.

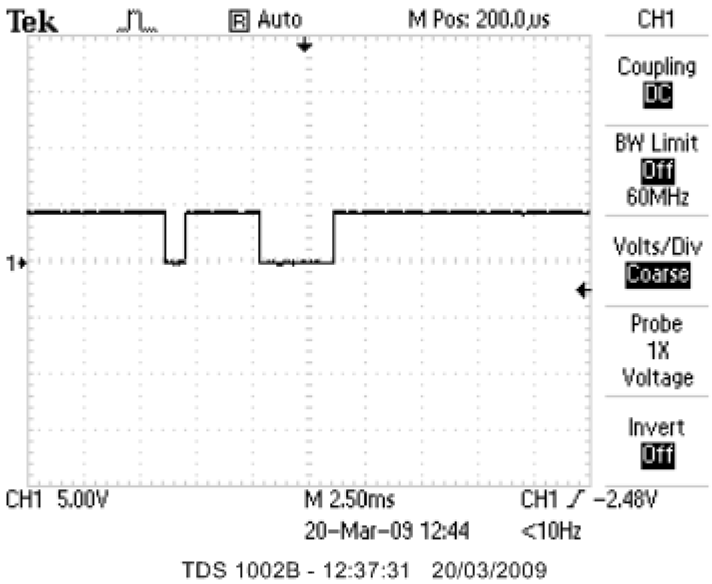


Figure 3-19 MCU Tx Pin Output Waveform @ Serial # 15

Further Tests results for the output waveform at the Tx Pin of the MCU with different serial numbers have been added into Appendix J.

The circuit for the Micro Tx transmitter was tested separately before connecting it with the MCU circuit. The transmitter was given a plain 2.5 Volts DC supply using a standard power supply. During initial testing it was observed that the behaviour of the 100 uH RF choke recommended in the product data sheet [5] was capacitive rather than being resistive. It was then decided to reduce the size of the RF choke and a 1 uH RF choke was used instead. The Rhodes and Schwartz Network Analyzer was used to verify that the frequency output of the Micro Tx transmitter is at 433.92 MHz Figure 3-20 below shows the screenshot of the waveform at the network analyzer. The oscilloscope marker in the figure is set at 433 MHz waveform spike.

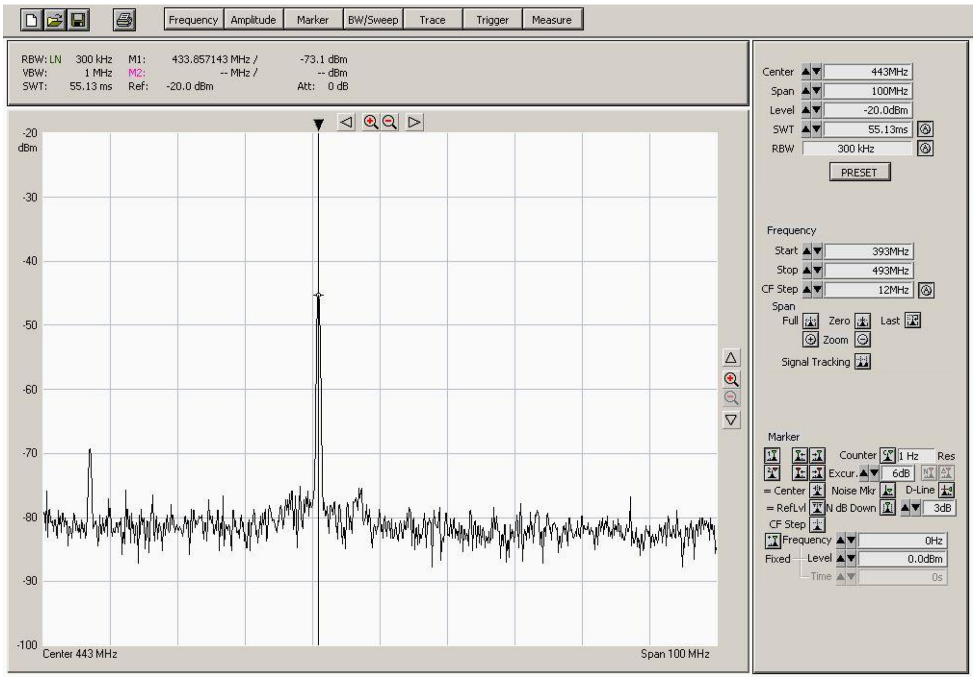


Figure 3-20 Frequency Spectrum for Micro Tx Transmitter @ 433 MHz

After confirming that the transmitter circuit and its output is satisfactory, the Transmitter circuit was then connected to the MCU circuit and the complete tag was tested.

3.5.3 Complete Tag Testing

The complete tag was tested using two different techniques. Initially the complete tag was powered up and the Tektronix Network Analyzer was used to observe the frequency spectrum output at different tag serial numbers. Figure 3-21 below shows a screenshot of the output waveform observed at the network analyzer when the tag serial number was set to # 63.

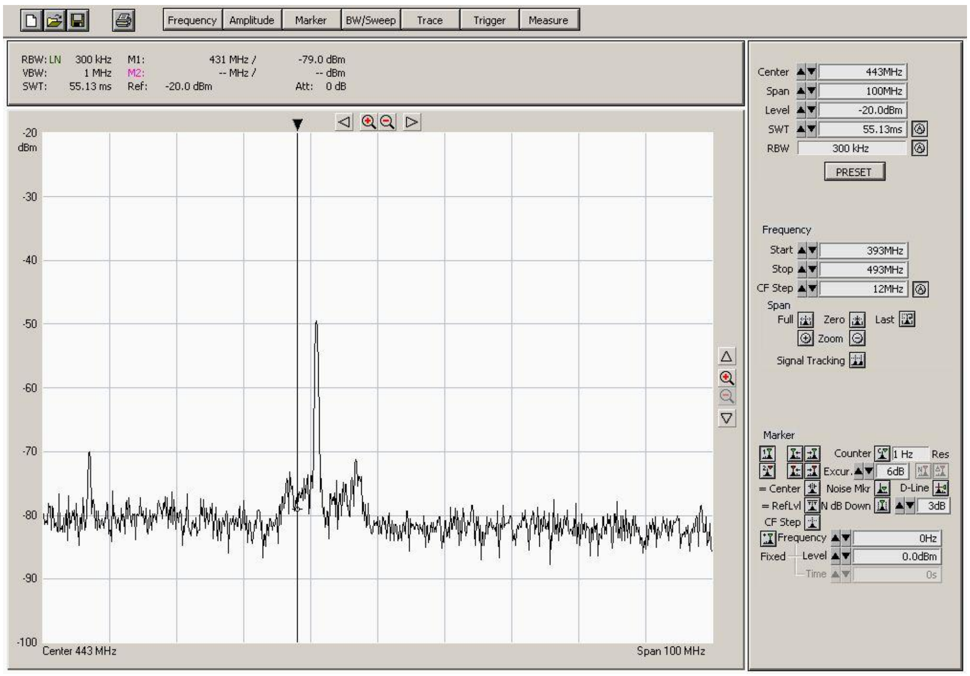


Figure 3-21 Frequency Spectrum for Complete Tag with serial # 63

The spike shown in the figure above is at 433 MHz confirming that the tag was operating at the right frequency. In order to check whether the output from the tag was correct, the “ICOM Radio Software” was used to detect the output from the tag. The radio software also provides the sound output of the received signal and its software interface provides related information about the received signal. Figure 3-22shows a screenshot of the radio software when the tag was transmitting at tag serial # 63.

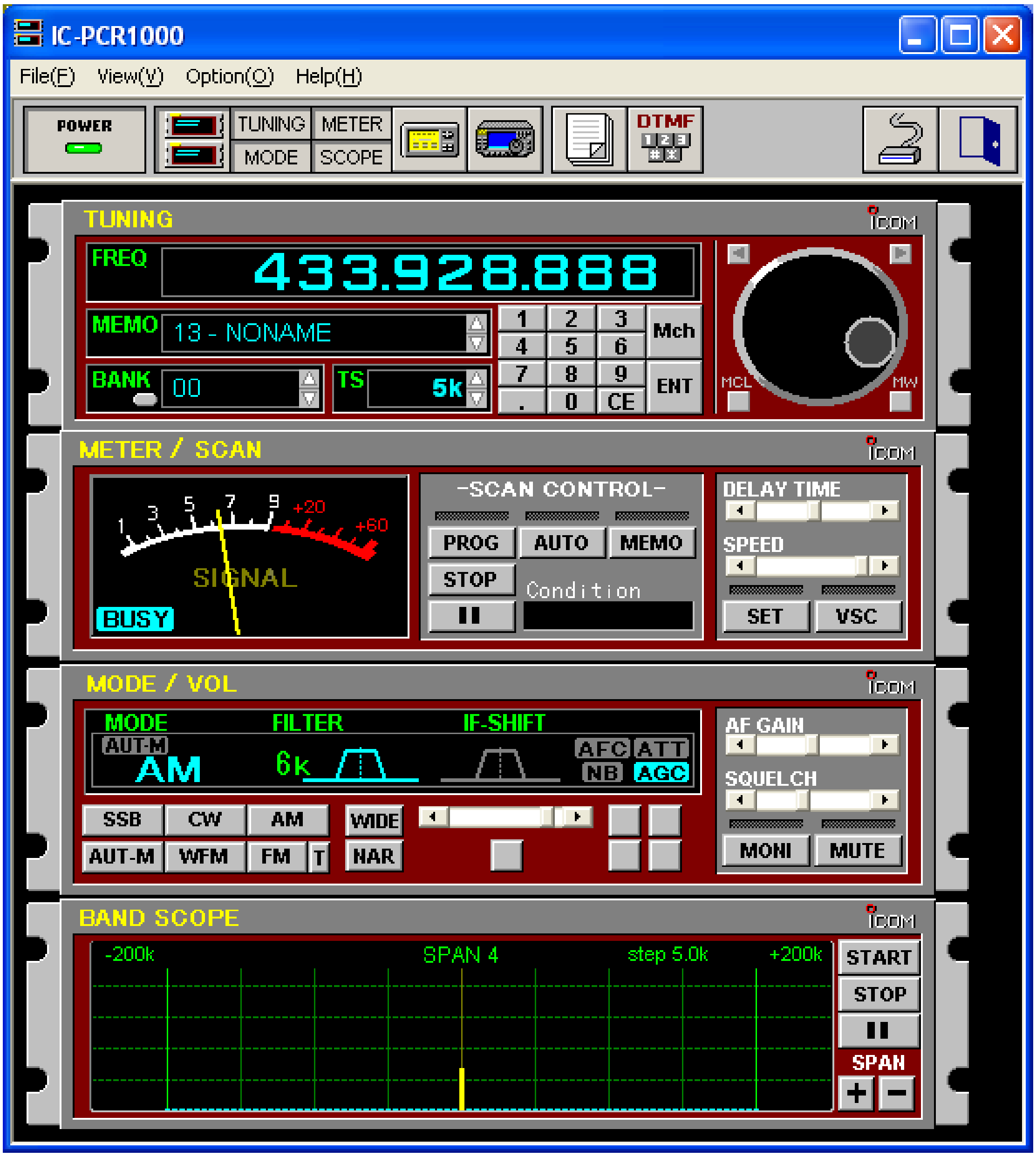


Figure 3-22 Output of the Radio Software @ Tag Serial # 63

As it is clear from the figure, the received signal was at AM frequency of 433.928 MHz. The software also generated a sound signal which could be listened to using the speakers, the pitch of the sound increased as the tag number was increased to a higher decimal number indicating that more number of data bits were being transmitted.

3.5 Summary

At the end of the Radio Tag development phase an Active Radio Tag was successfully designed, assembled and tested using a PIC 16F88 microcontroller and a Micro Tx Transmitter Module. The tag operates at an Amplitude Modulation (AM) frequency of 433 MHz, the radio circuit was first assembled and tested on a prototype breadboard and later on the design was transferred over to a Vero board.

Different software versions were designed and tested during the software development phase and at the end of the testing stage a smaller, more efficient tag code was chosen as the final code for the tag microcontroller.

Below are the changes that were made to the Radio Tag hardware and software during the testing stage:-

- A 100 uF capacitor was added to the V_{DD} pin of the microcontroller to stabilise the power supply.
- The 100 uH RF choke used in the Micro Tx application circuit was changed to a 1 uH RF choke to make its use resistive rather than capacitive.
- The tag serial number reading technique was changed to bit manipulation to reduce code size and increase efficiency.

The following are the additions made to the Radio Tag hardware during the testing stage:-

- A Green LED was connected to the Tx (RB5) pin of the MCU to indicate the data transmission.
- A wire was soldered close to the Tx (RB5) pin on the Vero board, to be used as test point while testing the output of MCU and for testing using serial data link.

4. Base Station (RF Receiver/Reader)

The Radio Tag Tracking System required a Base Station, which according to project aims, was expected to keep track of the Radio Tags associated to it. The base station (or receiver) was supposed to raise an alarm if any of the radio tags was missing. The following sections in this chapter detail the steps taken in design, assembly and testing of the Base Station.

4.1 Hardware Selection

Just like the Radio Tag, the hardware selection for the Base Station had an important role in this phase of the project. According to conceptual system block diagram (Figure 4-1) a base station was expected to have a microcontroller, LCD Screen, an RF Receiver, Antenna and an alarm system.

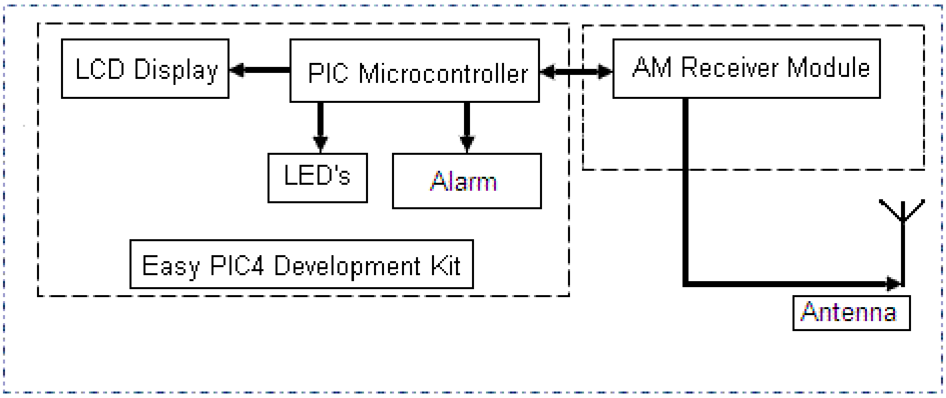


Figure 4-1 Conceptual Block Diagram of Base Station (Reader)

The EasyPIC4 development board used during Radio Tag development was chosen as the ideal hardware solution to incorporate all these components in one prototype. The development board comes with a PIC 16F877A microprocessor and a 16 x 2 LCD. The PIC MCU was therefore chosen as the MCU for base station and LCD was used to display data. The development board also has 36 LED's (see Appendix G) which could be used to indicate any circuit operation. The development board has separate 10 pin port access pins which could be used to connect the RF Receiver and alarm system to the microcontroller.

After hardware research and consultation with experts, the AM2000 RX433 receiver was chosen as the suitable RF receiver to interpret the signals from radio tags. The AM2000 receiver works at the UK Licence exempt frequency of 433 MHz and uses Amplitude Modulation Technique to interpret the radio signals. The Receiver is manufactured and recommended by the manufacturers of the Micro Tx Transmitter Module used in the Radio Tag. The following sub-sections further detail the features of the components used in the Base Station.

4.1.1 PIC 16F877A

The PIC 16F877A microcontroller is a FLASH-based 8-bit microcontroller manufactured by Microchip. The MCU used in the base station comes in a 40 pin package and has a string of features that make it ideal to be used in the Base Station The MCU also supports USART communication making it useful for communication between radio receivers [20]. The table below highlights the most important features of the MCU relative to the project. For detailed information about the MCU architecture its datasheet [21] should be referred.

Table 5 PIC 16F877A Specifications

Parameter Name	Value	PIN Diagram
Program Memory type	Flash	
Program Memory(KB)	14	
CPU Speed (MIPS)	5	
RAM Bytes	368	
Data EEPROM (bytes)	256	
Timers	2 x 18-bit, 1 x 16-bit	
ADC	8 ch, 10-bit	
Comparators	2	
Serial Comms	MSSP, USART	
I/O Ports	Ports A, B, C, D, E	
Instruction Set	35 Instructions	
Resets	POR, BOR	
Temperature Range (C)	-40 to 125	
Operating Voltage Range (V)	2 to 5.5	
Pin Count	40	

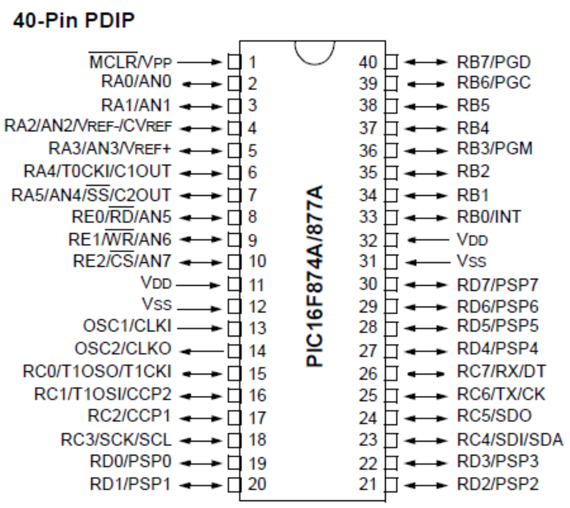


Figure 4-2 PIC 16F877A Pin Diagram[20]

Due to the fact that the MCU was supplied with the development board the sourcing cost for the MCU could be considered negligible. Details of Electrical Characteristics of the microcontroller have been added in Appendix M along with datasheet pages related to the project.

4.1.2 AM2000 RX 433 Receiver

The AM2000 RX 433 Receiver is a simply to apply, AM receiver for operation at frequencies of 418MHz, 433MHz and 868MHz. The low radiated emissions from the receiver ensure compliance with EMC requirements. The module requires only a clean DC supply of 5volts, an antenna and a suitable device for decoding the incoming digital data [22].

All transmitters and receivers require antennas in order to work efficiently; the AM2000 receiver also requires a ¼ wave whip antenna (approximately 16cm) for best performance. The antenna, however, should be mounted in “free space” and well away from any conductive objects or surfaces [22]. Table 4-2 details the absolute maximum ratings and performance specifications of the AM2000 Receiver [22].

Table 6 Absolute Maximum Ratings of the AM2000 Receiver [22]

Parameter Name	Value	Units
Supply Voltage	0.3 to +5.25	Volts
Receive Frequency	433.92	MHz
Sensitive for 6dB S/N	-103	dBm
Supply Current	8	mA
Shutdown Current	25	uA
Data Output (logic 0)	0 – 0.5 (50k Load)	Volts
Data Output (logic 1)	Min 4.5 (50k Load)	Volts
Size	40 x 15.4	Mm
Operating Temperature	0 to +70	C

Figure 4.3 illustrates a picture of the AM2000 receiver, datasheet pages relative to the project have been added in Appendix N.

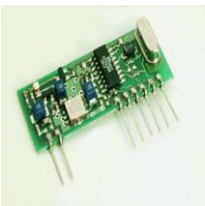


Figure 4-3 Picture of an AM2000 RX 433 Receiver [22]

4.1.3 EasyPIC4 Development Board

The Information about EasyPIC4 development board has already been provided in section 3.1.2 and detailed information is added to Appendix F. The development board was used to integrate the Base Station components together in one place. The PIC 16F877A MCU was placed in the DIP40 socket of the board to be programmed and when the Base station was in operation. The LCD used with the board was a 4-Bit 16 x 2 LCD which could display two rows of up to 16 characters each row.

The Direct Port Access Pins [8] (Appendix F) on the board were used to connect the AM2000 receiver to the Microcontroller. Further details about the base station design are given in the next section of this chapter.

4.2 Circuit Design and Assembly

The circuit design phase for the Base Station did not provide much technical challenge as all the components could easily be fixed onto the development board and no separate circuit diagrams were required in the MCU circuit part of the base station. However, an important part of the Base Station hardware design was the integration of the RF Receiver and the MCU. The AM2000 receiver required separate circuit design to ensure accurate operation. The product datasheet [22] was consulted to identify the right pin connections and instructions to enable the receiver. The detailed information about the circuit design and assembly of the receiver is given in section 4.2.2.

4.2.1 Power Management

During stand-alone operation the EasyPIC4 development board could either be powered up by an external power supply (between 8V -16V) or by a USB connection to the computer (5V). The power supply to the MCU was therefore provided through the development board.
The AM2000 Receiver requires clean 5V DC supply and draws 8mA current during normal operation.

The development board has 10 Direct Port Access Pins that can be used to access the individual pins on the MCU. The 10 pins also include the Vcc (5V) and Ground (0V) pins and since the individual MCU I/O pins can source up to 25mA of current, the AM2000 receiver was powered up through those pins. The whole Base Station hardware was therefore powered up through the development board. The development board in turn, was powered up through a USB connection to the computer.

4.2.2 AM2000 Receiver Circuit Design and Assembly

The AM200 receiver circuit was assembled on a Colander Vero Board (see Appendix L) to ensure good ground plane was provided to the receiver for RF frequency operation. The ¼ wave antenna used with the Receiver was identical to the antenna used with the Micro Tx module. The antenna was mounted on the top side of the Vero Board on the ground plane using a SMA connector. The connector legs were again bigger in the diameter than the through holes and therefore the holes on the board were enlarged by drilling through them. Figure 4.4 below shows the pin diagram for a

In order to enable the receiver module following steps were taken in the circuit assembly

- The GND (Pin 10) and RF GND (Pin 1) pins of the module were connected to the 0V earth plane on the board.
- The Shutdown pin (Pin 12) was also pulled down to enable the module
- The bandwidth selector jumpers (SEL 1 and SEL 0) were already set to logic low (0) to enable the bandwidth selection of 1.25 KHz (to match 1200bps data rate of the Tag).

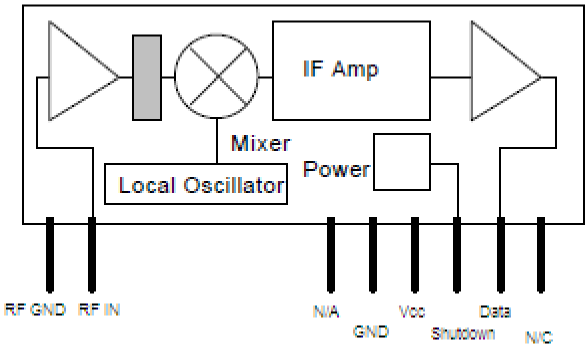


Figure 4-4 AM2000 RX433 Receiver Pin Diagram [22]

In order to eliminate any unwanted oscillations in the circuitry on the Vero Board, the receiver and the antenna were placed as close to each other as possible. A 10 Pin socket was soldered into the Vero Board to hold the AM Receiver. This was done to avoid soldering the sensitive pins of the Receiver on the board and potentially damaging the circuitry due to excessive heat during soldering. This also provided modularity in the circuit as the receiver module could easily be taken off from the circuit board (if required).

4.2.3 Complete Base Station Assembly

The complete Base Station was assembled by connecting the AM2000 RX module with the EasyPIC4 development board by using a 3-wire cable. The cable was made by soldering three colour coded wires to a 10 pin connector. The two wires (Red and Black) were used for the power supply (5V and 0V respectively) to the receiver circuit. The third wire (purple) was used to transmit data signals between the receiver and the microcontroller.

One end of the end of the 3-wire cable was connected to the direct port access pins for PORT C. The RC7 Pin of the MCU (see figure 4-2) is the RX Pin, which is used to receive the USART data. The data cable used in the interconnection was therefore connected between the RC7 pin and the DATA pin on the AM2000 RX module. The figure illustrates the complete Base Station hardware, with important components indicated using pointers.

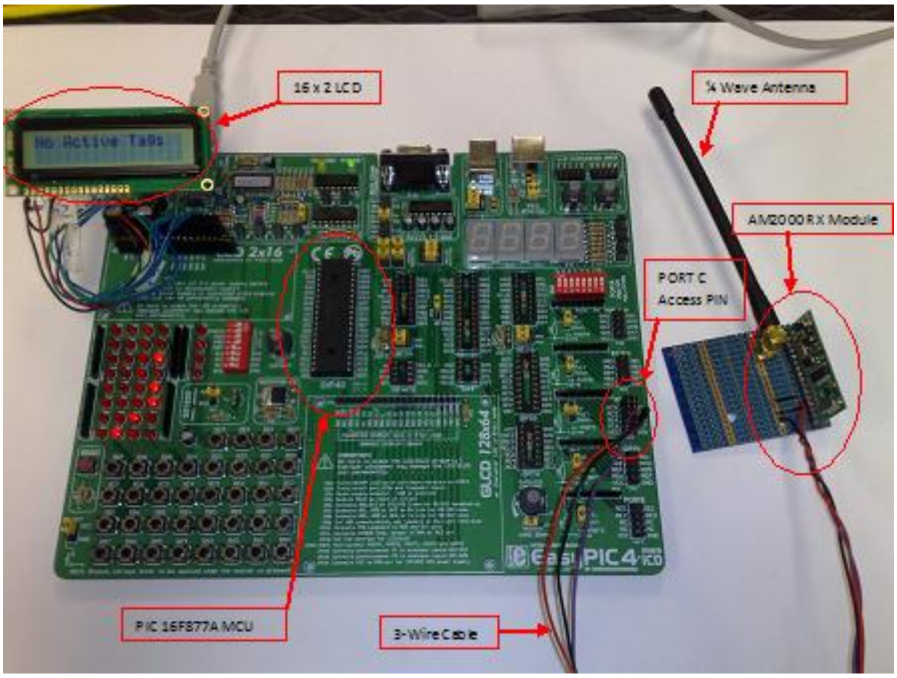


Figure 4-5 Complete Base Station

4.3 Microcontroller Software Code

The program code for the PIC 16F877A was also written using the MikroC programming software. Details about the programming software could be acquired from its user manual [18]. The program code was initially written to display the data received during wired communication between the Radio Tag and the Base Station. The software code explained below is capable of receiving data either wirelessly or through wired connection but after the testing stages, as explained in section 4.4, the software code was not expanded to include algorithms for tracking more than one radio tag.

Just like the Radio Tag software code, the first step towards developing the software code from the base station was to identify the software requirements and produce a basic data flow diagram for the system. The data flow diagram for the software code has been added into Appendix I. The main objectives identified for the software code included:-

- Display Text Messages including information about active tags, missing tags
- Activate an alarm if any of there are no Active Tags or if a Tag is Missing
- Store and Process data received through USART
- Time the two consecutive signals from a tag and if time difference is more than a pre-defined time limit, activate the alarm.
- Code feasible for data received through wireless and/or wireless communication

During code development, the modular approach was again adopted and the code was divided into smaller functions and any repetitive tasks were distributed in loops. Figure 4-6 below illustrates the initial part of the software code. Different versions of the code were developed and tested before a working code was selected. The code discussed in this report is the third version of the code. As part of the normal code writing practice, all of the important commands and functions were thoroughly commented to highlight function of each command line. The initial lines in the code file were dedicated to list details about the file name, name of the project, function of the project, programmer's name, and code version. The information has been enclosed by the standard C language comment operators "/*" and "*/".

The next line code defines a constant which is the length of the buffer being used in the code to store the data received through USART. Lines 19 – 26 define the different global variables being used within the program, the variables include a look-up array, the indexes for different loops, a char variable, and an array with different tag numbers already defined in it.

Figure 4-6 below illustrates the initial section of the software code that has been explained above.

The part of the code between lines 29 and 27 contains the function prototypes for all the functions that are used in the code.

```
 1: /*************************************************************************
 2: * Radio Tag For Item Tracking                                            *
 3: * (Base Station Code)                                                    *
 4: **************************************************************************
 5: * Filename: Tag Rx.c                                                     *
 6: * Date: 04/03/09                                                         *
 7: * File Version: 3.0                                                      *
 8: * Compiler: MikroC Compiler                                              *
 9: * Programmer: Ramiz AHmed                                                *
10: * Course: (BEng) Digital Systems & Computer Engineering                  *
11: **************************** Variables *****************************************/
12: //char *text0 = "Tag ";
13: //char *text1 = "Tracker";
14: //char *text2 = "Active";
15: //char *text3 = "Tag";
16: //char *text4 = "Missing";
17: #define buffer_length    35
18:
19: int rx buffer[buffer length];
20: int tag lookup[3][2];
21: int column = 0;
22: int row    = 0;
23: char tag_temp[4];
24: int g;
25: int i;
26: int j;
27:
28: int tag array [3][2] ={{1,0}, {2,0}, {3,0}};
29: /**************************** Functions *****************************************/
30: void pic setup();         // Initialise Port & USART Values for PIC
31: void welcome msg();       // Displays a Welcome Message on Power Up
32: void scan msg();          // Displays Message Before Scanning for Tags
33: void no tag();            // Displays Message if No Active Tags
34: void clear buffer();      // Clear the Receive Buffer
35: void ser rx(void);        // Receive the Data from the Receive Port
36: void disp tag active(int number); // Display What Tags are active
37: void disp tag missing() ;         // Display if a Tag Goes Missing
38: /*************************************************************************
```

Figure 4-6 Base Station Software Code Section 1

Table 7 below lists all the functions defined in the software code with the description of the functionality of each of the functions.

Table 7 Function Names and their operation

Function Name	Description
pic_setup()	Runs Appropriate commands to configure interrupts, ports , and USART initialization
welcome_msg()	Displays a welcome msg "Univ of Herts" and then " Tag Tracker"
scan_msg()	Displays a message " Scanning For Tags"
no_tag()	Displays a message at start-up " No Active Tags"
clear_buffer()	Clears the Receive Buffer Array
ser_rx()	Receives the Data Through USART and stores it in rx_buffer
disp_tag_active()	Displays message " Tag " Tag# "Active" – Tag# is the tag number in buffer
disp_tag_missing()	Displays message " Tag " Tag# "Missing" – Tag# is the number of tag

The important aspect of the text messages being displayed in different functions was the placing of the text on the LCD Screen. Since the LCD being used to display messages was only a 2 rows by 16 columns, the number of possible character to be displayed in each line was 16. Therefore, special care needed to be taken to display the information so that none of the characters are overlapped and incorrect text being displayed on screen. The problem was resolved by carefully choosing the text to be displayed. A LCD Map was created and numbers of characters in each of the messages being displayed were counted and then their position was calculated. Below is the list of the text messages that are displayed in the software and the number of characters and spaces in each message.

Table 8 Number of Characters & Rows Required in Each Text Message

Message	No of Characters + Spaces	Total Characters	Rows Required
Univ of Herts	4 + 1 + 2 + 5	12	1
Tag Tracker	3 + 1 + 7	11	1
Scanning For Tags	8 + 1 + 3 + 1 + 4	17	2
No Active Tags	2 + 1 + 6 + 1+ 4	14	1
Tag XXX Active	3 + 1 + 3 + 1 + 6	14	1
Tag XXX Missing	3 + 1 + 3 + 1 + 7	15	1

The calculations above show that most of the message could easily be displayed on one row of the LCD and the second row could be used to display different information. Since the "Scanning For Tags" message was just an informative message therefore it was divided onto two rows.

The real complication was in displaying the Tag XXX Active/Missing messages. Since the maximum number of possible tags to be tracked by the Base Station is 256 it was assumed the number cannot be more than 3 digits long. However, the data being received through the USART was of integer data type and the LCD display library in MikroC can only display characters. Therefore the tag serial number data needed to be converted to a character string before it was passed to the LCD display library.

In each of the display messages listed in Table 5 above, the LCD cursor was turned off and screen was cleared using the following commands

```
Lcd_Cmd(Lcd_CLEAR);
Lcd_Cmd(Lcd_CURSOR_OFF);
```

The text was then passed to the library function by using the LCD_out command as shown in the examples below

```
Lcd_out(1,1,"Univ of Herts");
Lcd_out(2,1,"Tag Tracker");  // 2 x 16 LCD
```

In case of the Tag Active/Missing messages, rather than displaying the words on the current cursor position, the position of each of the words was specified. The position for the converted tag number was also specified as shown in the example below:-

```
Lcd_out(1,1,"Tag");
Lcd_out(1,4,tag_temp);
Lcd_out(1,9,"Active");
```

The number 1 in the message above specifies the row and the numbers 1, 4, 9 in each of the messages specify the exact column where the word should start. Each of the messages were displayed for a specific period of time using a delay function shown below, after the delay the handle of the processor is returned to the main program.

```
delay_ms(100);
```

Figure 4-7 below shows the section of the code where the text display messages are defined.

```
63: Lcd out(2,1,"Tag Tracker");  // 2 x 16 LCD
64: //Lcd out(1,1,"Tag Trac");   // 1 x 16 LCD
65: //Lcd out(2,1,"ker");        // 1 x 16 LCD
66: delay_ms(1000);
67: }
68: /**************************** Tag Scan Message ********************************/
69: void scan_msg()
70: {
71: Lcd Cmd(Lcd CLEAR);
72: Lcd out(1,1,"Scanning For Tag");
73: delay_ms(500);
74: }
75: /**************************** NO Tag Message **********************************/
76: void no_tag()
77: {
78: Lcd Cmd(Lcd CLEAR);
79: Lcd out(1,1,"No Active Tags");
80: delay_ms(500);
81: }
82: /**************************** Tag Active Message ******************************/
83: void disp_tag_active(int number)
84: {
85: Lcd Cmd(Lcd CLEAR);
86: Lcd Cmd(Lcd CURSOR OFF);
87: byteToStr(number,tag_temp);
88: // First Tag Line
89: Lcd out(1,1,"Tag");
90: Lcd out(1,4,tag temp);
91: Lcd out(1,9,"Active");
92: delay ms(100);
93: // Second Tag Line
94: }
95: /*************************** Tag Missing Message  *****************************/
96: void disp_tag_missing()
97: {
98: Lcd Cmd(Lcd CLEAR);
99: Lcd_Cmd(Lcd_CURSOR_OFF);
100:
101: Lcd out(1,1,"Tag");
102: Lcd out(1,5,tag temp);
103: Lcd out(1,9,"Active");
104: // Second Tag Line
105: }
106: /*****************************************************************************/
```

Figure 4-7 Base Station Software Code Function Definition Section

Lines 109 -136 contain the *main()* function which forms the body of the whole tracking software. At line 112, the *pic_setup()* function is called, which is used to configure the ports and USART in the microcontroller. Within the function, Port RB7 is declared (to be used to activate the alarm) as an output and initialized at logic zero (0). The USART is initialized at 1200 baud rate to match the data rate of the Radio Tags. The LCD is initialized at port Port D of the microcontroller.

```
Usart_init(1200);  //Initialise Usart @ 1200 Baudrate, 8 Bit, No Parity Bit
TRISB.F7 = 0;
Portb.F7 = 0;
TRISD = 0x00;
Lcd_init(&PortD);
clear_buffer();
```

At line 113 and 114 the *welcome_msg()* and *scanning_msg()* functions are called which display the appropriate messages on the LCD respectively. Lines 116 – 135 contain the do...while loop which performs the tag tracking function. At the beginning of the loop is a conditional IF statement that checks if there is any data ready to be read from the USART port, if the data is available the statement is false and the program skips the commands within the conditional statement and executes to the next conditional statement. However if there is no data on the USART to be read, the statement is true and the program executes the following commands:

```
no_tag();
portb.f7 = 1;
lcd_cmd(lcd_clear);
clear_buffer();
```

In these commands, a message “No Active Tags” is displayed on LCD, the receive buffer is cleared and the Alarm Output Pin is Asserted.

After skipping the first conditional statement, the program then comes to the second conditional statement at line 125. This line again checks whether data is available on USART. If data is available the code within the statements is executed, otherwise the program skips the command lines and goes through the loop section again. Within the conditional statement commands (listed below), the program goes into another FOR loop.

```
Portb.F7 = 0;
for(i=0;i<1;i++)
{
rx_buffer[i] = USART_Read(); // put char in element & then increment index
disp_tag_active(rx_buffer[i]);
}
```

Within the FOR loop, the data available on the USART is read in to the *rx_buffer[]* array and at the same time the same data element from the *rx_buffer* is passed on to the *disp_tag_active()* function which in turn converts the received integer data to characters and displays the active tag message on the LCD. After completing the FOR loop, the program escapes the second conditional statement goes through the do...while loop again.

The program was carefully debugged and after successful compilation the code was downloaded on to the PIC 16F877A microcontroller. The program was tested in the testing stage detailed in the next section of this chapter.

4.4 Testing

The testing phase of the Base Station was conducted in two stages. In the first stage, A radio tag was connected to the Base station using a wired communication link. However in the second stage, the wireless communication through RF Frequency was attempted. The details of both test stages are given below.

4.4.1 Wired (Serial) Communication Testing

During this stage, the radio tag prototype was connected to the Base Station using a serial wire connection. As shown in figure 4-8 below, the Tx Pin of the MCU in the Radio Tag was connected to the RC7 pin in the direct port access pins on the Development board.

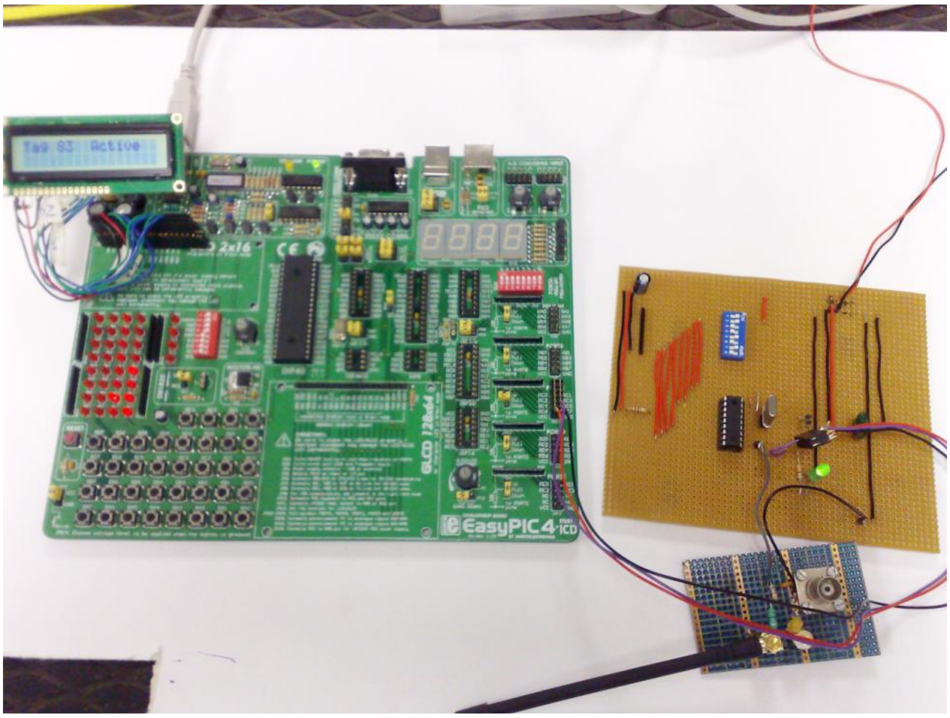


Figure 4-8 Wired Communication Testing Setup with Radio Tag & Base Station

The Radio Tag was powered up by a standard laboratory 5V power supply, whereas the 5V power supply to the development board was provided by using the USB2.0 cable. After Powering up both the circuits, the DIP switches on the Radio Tag were altered to specify a tag serial number and the expected output on the Base Station LCD was observed. Different combinations of the tag serial numbers were used to ensure correct operation of the software code. Figure 4-9 below shows the result observed on the LCD screen when the tag number on the Radio Tag was set to 83.

Figure 4-9 Complete Base Station

4.4.2 Wireless (RF) Communication Testing

After successful completion of wired testing phase, the wireless, RF communication link was tested. The wireless communication link was attempted by connecting the AM2000 RX receiver to the EasyPIC4 development board. The complete radio tag (MCU + TX) was powered up using a standard 5V laboratory power supply. Both the circuits were powered up and the LCD screen was observed for any signal reception. Figure 4-10shows the setup for the RF Communication Link Testing.

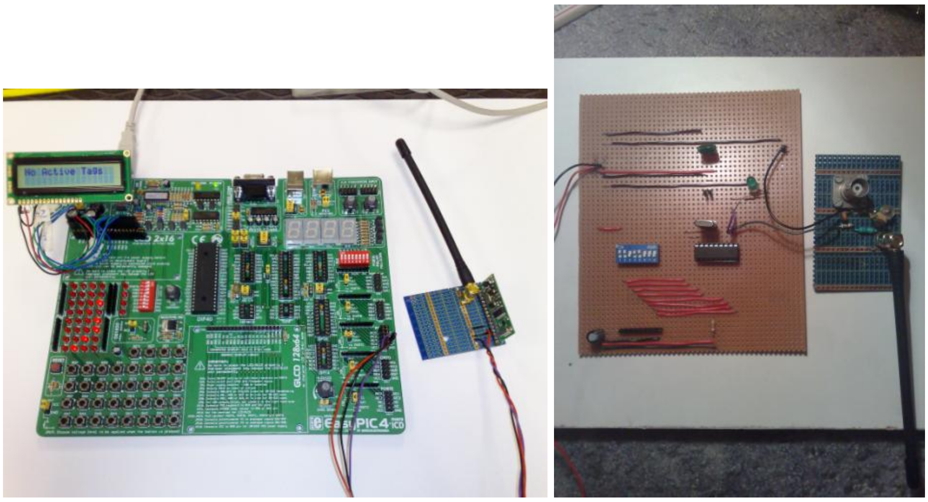


Figure 4-10 Wireless Comm. testing setup with Tag & Base Station Separate

After multiple testing sessions, RF communication link between the two system components could not be established. The Radio Tag had already been tested and its correct operation was already confirmed therefore the Base station circuit was checked for any abnormalities and wrong connections. The module datasheet was again consulted but no fault could be identified. The communication link was attempted again and voltage levels on each of the pins on the AM2000 RX Module were monitored and the waveforms were observed on the oscilloscope but no significant activity could be identified.

After all unsuccessful attempts, the manufacturers for RX module were contacted to confirm any known issues with the module. It was then, the manufacturers responded with the fact that the AM2000 Rx Module does not support USART, the receiver module did not have any radio software as well and therefore the data received on the module was nothing more than RF noise and the microcontroller could not detect it. The module is a recommended receiver for the Micro TX transmitter and the product datasheet [5] does not mention anywhere whether or not the module supports USART transmission. Therefore, the manufacturer's word had to be believed to justify the incompatibility of the Receiver Module.

Due to lack of time, sourcing of a new correct receiver module was not pursued. Although a new correct receiver module was recommended by the manufacturers, which is discussed in the Conclusion chapter of this report. A copy of the email communication between the author of this report and the module manufacturers has been added in Appendix O for evidence and reference to the recommended Radio Receiver.

4.5 Summary

During the Base Station development stage of the project plan, a Radio Tag tracking base station was developed. The Base Station was based on the components installed on the Easy PIC4 development board, the microcontroller used in the system was a PIC 16F877A microcontroller. For Receiving RF signals, the AM2000 RX433 Receiver Module manufactured by Low Power Radio Solutions [22] was used.

The circuit was assembled using professional circuit assembly practices, the code for the microcontroller was also developed using best possible approach towards problem solving. The Base station was testing in two stages; the wired communication testing stage was successfully completed, however, the RF communication testing stage could not be completed due to an absence of USART port in the Receiver Module. Further details about recommendation on the new receiver module are discussed in the next chapter of this report.

5. Conclusion

This chapter provides a brief summary on the work carried out during the project, and discusses the overall outcome of the project. The successful achievement of project objectives and tasks set at the beginning of the project is also discussed.

This chapter also comments on the efficiency of the overall project management, provides overview of the final costs of the project according to market point of view.

The last section of this chapter discusses the recommendations on the supplementary work related to the overall Radio Tag Tracking System and also highlights precautions regarding certain components and overall project progress.

5.1 Project Outline and Achievements

The main aim of this project was to develop a system which could track the radio tags associated with the system. The main part of the project was the development of a suitable radio tag and consequently a base station which could keep track of the base system. As explained in chapter 1 certain operational criterion was set for both the radio tag and the tracking system. The criterion for the radio tag included the compact size, battery operation and RF frequency operation. The criterion for the Base Station required a display, an alarm system and a suitable RF signal receiver.

The selection of suitable RF Frequency to work on required a careful research, to identify a low power, licence exempt frequency. The 433 MHz operating frequency was chosen after consulting the documentation on communication regulation imposed by the local regulation authority OFCOM.

5.1.1 System Hardware Design and Assembly

The Radio Tag hardware was selected after considering all the operational requirements. A PIC16F88 microcontroller was used to read in the tag serial number selected using 8 DIP switches, the miniature Micro Tx transmitter working at AM 433 MHz frequency manufactured by Low Power Radio Solutions was selected as a suitable RF transmitter. A ¼ wave antenna was used for transmitting radio signals from the transmitter. The prototype radio tag was built in two stages, the MCU circuit was assembled onto a prototyping Vero board and the Transmitter circuit was developed on a Colander Vero Board which had sufficient ground plane. The two circuits were then combined using wires. The complete Radio Tag hardware and software were tested using different instruments and techniques and a successful radio transmission was achieved.

The Base Station hardware selection did not require extensive research as most of the components were already available. The EasyPIC4 development board was used as the base station backbone, a PIC 16F877A microcontroller was used as the control logic microcontroller and it was plugged into the board along with the LCD screen. The AM2000 RX433 Receiver module manufactured by Low Power Radio Solutions was selected as a suitable RF signal receiver.

The hardware assembly for the base station as most of the components were simply plugged into their sockets on the development board. The AM2000 receiver was mounted into a socket soldered onto a colander Vero Board. The circuit board also had a suitable ¼ wave antenna mounted on it for reception of the radio signals.

The hardware and software testing phase of the project was divided into two phases, the initial base station performance was tested by creating a wired communication link between the Radio Tag and the Base Station. The Direct Port Access pins on the Development board were used to connect the Transmit pins of the radio tag to the base station microcontroller. Successful wired communication link was created after conducting multiple tests at different times using variable radio tag serial numbers.

During the second testing stage, the wireless RF communication link between the Radio Tag and the Base Station was attempted. The testing stage was unsuccessful as a Radio transmission could not be achieved. This was due to the reason that the AM2000 Receiver did not have any radio software and did not support USART communication and therefore valid data could not be transferred between the receiver and the microcontroller.

The recommended receiver module was carefully analysed and is discussed in the recommendations section. Due to lack of time in the project, a replacement receiver was not purchased and therefore the RF Communication stage of the project is still incomplete.

5.2 Project Time Plan and Costing

The project was managed according to the tasks outlined in the initial time plan created at the commencement of the project. Throughout the duration of the project, the task deadlines were adhered to and project tasks were updated upon completion. Some of the tasks suffered minor delays due to certain academic commitments but overall project progress was satisfactory.

The Project Time plan given in Appendix A shows some of the tasks are still in progress. This is because of the fact that, due to lack of time the Base Station hardware testing phase stage could not be completed.

Since the radio tag project has certain industrial application potential, the component expenditure was carefully monitored and all necessary care was taken to reduce the overall component costs. The School of Electronic, Communication and Electrical Engineering has a maximum budget allowance of £50. While, the overall component costs were a lot higher from the allowed budget, the costs were reduced by sourcing the costly EasyPIC4 Development Board from within the School. This allowed the £50 budget to be spent on purchase of Micro Tx transmitters and AM2000 Receiver. Some of the spare money after the major component purchase was used to purchase the antennas and other small but important components. The table in Appendix B lists the costing and quantities of all the hardware components used within the project. The table could also be used to rearrange or reduce hardware components and improve costing in future project work.

5.3 Recommendations for Further Work

Since the entire project objectives were not achieved at the end of the project duration. There is still a lot of room for further work in the project. A major part of the Radio Tag and base station development work was completed during the project. Further work could be done in improving the overall performance of the system hardware and achieve Radio communication as explained in the following sub-sections.

One recommendation on the further work is to divide the complete project in two sub projects. The Transmit only Radio Tag and Base Station development part should be allocated as one sub-project and the Transmit/Receive Tag and Portable Tag Tracker development part should be allocated as a different sub-project.

5.3.1 Radio Tag

The software code for the Radio Tag is complete and very efficient. The software could be improved to introduce data encryption to enhance the security aspect of the Radio Tags. Special attention should be given to improvement of the Tag circuit. The best thing to reduce the circuit size would be to transfer the complete tag circuit onto a Printed Circuit Board (PCB). The prototype only works on power supply from standard lab power supply therefore a battery power supply feature could also be added to the tag prototype. Spare components (PIC16F88 MCU and 2 x Micro Tx Transmitters) from the current project could be used to reduce component costs. Tag Circuit on PCB would mean the PCB loop antenna could be used for RF transmission, this could further reduce extra costs incurred in external antennas and would significantly reduce the overall Tag size.

Microchip, the manufacturers of PIC 16F88 microcontroller also manufacture MCU's with Built-in RF Transmitters. One such low cost RF microcontroller is XXX, which operates at the licence exempt frequency of 433MHz. Further research into the operation of this microcontroller is recommended prior to development of a PCB for the Radio Tag. If the above said MCU is found feasible for the project application, this could not only reduce the project costs and size, it could improve the potential for industrial application of this research project.

To summarize, transfer of Tag circuit to a PCB is strongly recommended, however this should only be done after exploring the possibility of low cost RF microcontrollers during the feasibility study stage in the future project.

5.3.2 Base Station

The current Base Station circuit is currently assembled onto an EasyPIC4 Development Board, which requires that it should always be connected either to a mains power supply or a computer for operation. Due to selection of a wrong type of receiver module, the RF communication could not be achieved between the radio tag and the base station. However, module manufacturer was contacted and a suitable receiver module was identified.

In order to complete the Base Station circuit and the tracking system, the first step should be to transfer the MCU, LCD and Receiver onto a smaller circuit board, ideally a PCB. The stand-alone base station could then be powered up using a battery. Extra components including the alarm siren could be added onto the circuit board. Instead of using a Receiver, a Transceiver (Transmitter-Receiver), at little added cost, could be attached to the Base Station which could assist in later stages of the project when handheld tracking station would be developed.

The recommended receiver is an "EASY-RADIO 433-4MHz Receiver" [23] (see Appendix O) manufactured by Low Power Radio Solutions (LPRS). LPRS also manufacture a number of transceivers which could be used in both the tags and base station. Further research in these transceivers is recommended for development in the project. The module has only slight cost difference from the original module and it has features like built-in radio software as well as USART support.

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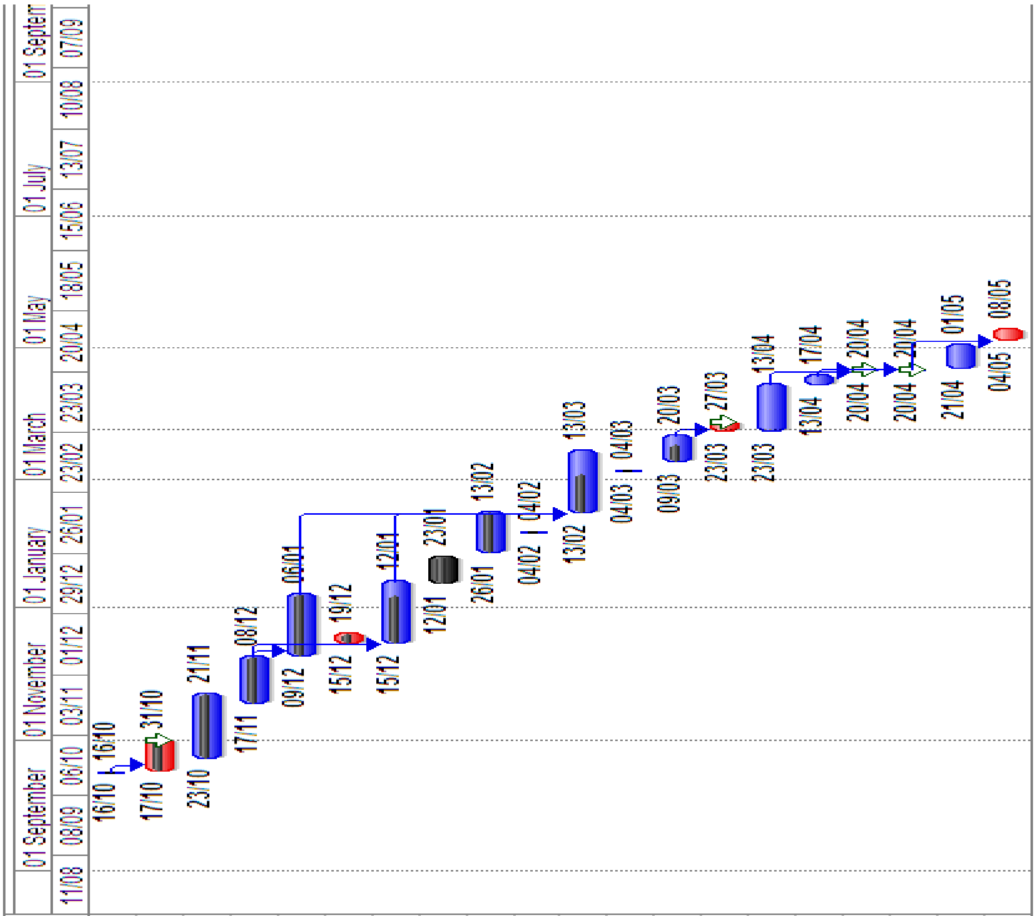
APPENDIX A Final Project Time Plan

ID		Task Name	Duration	Start	Finish
1	✓	First Supervisor Meeting & Project Brief	1 day	Thu 16/10/08	Thu 16/10/08
2	✓	Feasibility Study & Report Submission	11 days	Fri 17/10/08	Fri 31/10/08
3	✓	Literature Research	22 days	Thu 23/10/08	Fri 21/11/08
4	✓	System Block Diagram Design	16 days	Mon 17/11/08	Mon 08/12/08
5	✓	Transponder (Tag) Circuit Design & Simulat	21 days	Tue 09/12/08	Tue 06/01/09
6	✓	Project Seminar	5 days	Mon 15/12/08	Fri 19/12/08
7		Receiver Circuit Design & Simulation	21 days	Mon 15/12/08	Mon 12/01/09
8	✓	Revision & Exam Week (No Project Work)	10 days	Mon 12/01/09	Fri 23/01/09
9	✓	Software Development	15 days	Mon 26/01/09	Fri 13/02/09
10	✓	External Examiner Visit	1 day	Wed 04/02/09	Wed 04/02/09
11		Hardware Implementation (If Required)	21 days	Fri 13/02/09	Fri 13/03/09
12	✓	Project Interim Brief	1 day	Wed 04/03/09	Wed 04/03/09
13		Final Testing	10 days	Mon 09/03/09	Fri 20/03/09
14		Final Demonstration	5 days	Mon 23/03/09	Fri 27/03/09
15		Report Writing	16 days	Mon 23/03/09	Mon 13/04/09
16		Report Editing	5 days	Mon 13/04/09	Fri 17/04/09
17		Submissions (CD & Report)	1 day	Mon 20/04/09	Mon 20/04/09
18		Online Submissions	1 day	Mon 20/04/09	Mon 20/04/09
19		Preparation for Poster Presentation	9 days	Tue 21/04/09	Fri 01/05/09
20		Poster Presentation	5 days	Mon 04/05/09	Fri 08/05/09



APPENDIX B Final Component List

Name	Man. Code	Distributor	Stock Code	Unit Price	Quantity	Total Price
EasyPIC4 Development Board		microE		N/A	1	N/A
Micro Tx	LQ-TX433	LPRS		7.22	3	21.66
PIC 16F877A		microE		N/A	1	N/A
PIC 16F88		Stores		N/A	4	0
DIL Switch		Rapid	80-0312	0.51	3	2.04
8.0 MHz Crystal Oscillator		Rapid	90-0180	0.38	4	1.52
¼ Wave Whip Antenna	ANT-433MR	RS	532-4424	6.42	2	12.84
Antenna Connectors		RS	616-3422	1.26	3	3.78
Network Resistor		Stores		N/A	2	N/A
Breadboard		Stores		N/A	3	N/A
Vero Board		Stores		N/A	1	N/A
Total					**56.30**	

APPENDIX C Relevant Part of UK Frequency Allocation Table for Frequency Use

Frequency Allocation Band with 433 MHz frequency allocation shown.

Region 1	Region 2	Region 3
420 – 430MHz FIXED MOBILE except aeronautical mobile Radiolocation 5.269 5.270 5.271		
430 – 432MHz AMATEUR RADIOLOCATION 5.271 5.272 5.273 5.274 5.275 5.276 5.277	430 – 432MHz RADIOLOCATION Amateur 5.271 5.276 5.277 5.278 5.279	
432 – 438MHz AMATEUR RADIOLOCATION Earth exploration-satellite (active) 5.279A 5.138 5.271 5.272 5.276 5.277 5.280 5.281 5.282	432 – 438MHz RADIOLOCATION Amateur Earth exploration-satellite (active) 5.279A 5.271 5.276 5.277 5.278 5.279 5.281 5.282	
438 – 440MHz AMATEUR RADIOLOCATION 5.271 5.273 5.274 5.275 5.276 5.277 5.283	438 – 440MHz RADIOLOCATION Amateur 5.271 5.276 5.277 5.278 5.279	

APPENDIX D Relevant Part of UK Frequency Allocation Table for Radiated Power

Radiated Power Allowed in 433MHz Band

Code	Frequencies or Frequency Band	Radiated level
1. Non-specific SRDs including Telemetry and Telecommand		
1a	6765-6795 kHz	42 dBμA/m @10 m
1b	13553-13567 kHz	42 dBμA/m @10 m
1c	26·957-27·283 MHz	42 dBμA/m @10 m
1d	40·66-40·7 MHz	10 mW
1f	433·05-434·79 MHz	10 mW
1f1	433·05-434·79 MHz	1 mW
1f2	434·04–434·79 MHz	10 mW
1g	863-870 MHz	25 mW
1g1	868-868·6 MHz	25 mW
1g2	868·7-869·2 MHz	25 mW
1g3	869·4-869·65 MHz	500 mW
1g4	869·7-870·0 MHz	5 mW
1h	2400·0-2483·5 MHz	10 mW
1i	5725-5875 MHz	25 mW eirp
1j	24·00-24·25 GHz	100 mW. Devices operating in 24·05-24·15 GHz must employ a 2 MHz/mS minimum sweep rate
1k	61 – 61.5 GHz	100 mw
2. Tracking, Tracing and Data Acquisition.		
2a	457 kHz	7 dBμA/m @ 10 m
2b	169·400-169·475 MHz	500 mW
2c	169·400-169·475 MHz	500 mW
Note: 2b for Meter Reading, 2c for Asset Tracking and tracing.		
3. Wideband Data Transmission Systems		
3a	2400·0-2483·5 MHz	100 mW eirp
3b	5150-5250 MHz	200 mW eirp
3c	5250-5350 MHz	200 mW eirp
3d	5470-5725 MHz	1W eirp

APPENDIX E Relevant Pages from PIC 16F88 Datasheet

MICROCHIP **PIC16F87/88**

18/20/28-Pin Enhanced Flash MCUs with nanoWatt Technology

Low-Power Features:

- Power-Managed modes:
  - Primary Run: RC oscillator, 76 µA, 1 MHz, 2V
  - RC_RUN: 7 µA, 31.25 kHz, 2V
  - SEC_RUN: 9 µA, 32 kHz, 2V
  - Sleep: 0.1 µA, 2V
- Timer1 Oscillator: 1.8 µA, 32 kHz, 2V
- Watchdog Timer: 2.2 µA, 2V
- Two-Speed Oscillator Start-up

Oscillators:

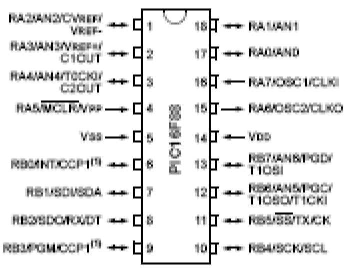
- Three Crystal modes:
  - LP, XT, HS: up to 20 MHz
- Two External RC modes
- One External Clock mode:
  - ECIO: up to 20 MHz
- Internal oscillator block:
  - 8 user selectable frequencies: 31 kHz, 125 kHz, 250 kHz, 500 kHz, 1 MHz, 2 MHz, 4 MHz, 8 MHz

Peripheral Features:

- Capture, Compare, PWM (CCP) module:
  - 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, 7-channel Analog-to-Digital Converter
- Synchronous Serial Port (SSP) with SPI™ (Master/Slave) and I²C™ (Slave)
- Addressable Universal Synchronous Asynchronous Receiver Transmitter (AUSART/SCI) with 9-bit address detection:
  - RS-232 operation using internal oscillator (no external crystal required)
- Dual Analog Comparator module:
  - Programmable on-chip voltage reference
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Pin Diagram

18-Pin PDIP, SOIC



Note 1: The CCP1 pin is determined by the CCPMX bit in Configuration Word 1 register.

Special Microcontroller Features:

- 100,000 erase/write cycles Enhanced Flash program memory typical
- 1,000,000 typical erase/write cycles EEPROM data memory typical
- EEPROM Data Retention: > 40 years
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Processor read/write access to program memory
- Low-Voltage Programming
- In-Circuit Debugging via two pins
- Extended Watchdog Timer (WDT):
  - Programmable period from 1 ms to 268s
- Wide operating voltage range: 2.0V to 5.5V

Device	Program Memory		Data Memory		I/O Pins	10-bit A/D (ch)	CCP (PWM)	AUSART	Comparators	SSP	Timers 8/16-bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)							
PIC16F87	7168	4096	368	256	16	N/A	1	Y	2	Y	2/1
PIC16F88	7168	4096	368	256	16	1	1	Y	2	Y	2/1

PIC16F87/88

1.0 DEVICE OVERVIEW

This document contains device specific information for the operation of the PIC16F87/88 devices. Additional information may be found in the "*PICmicro® Mid-Range MCU Family Reference Manual*" (DS33023) which may be downloaded from the Microchip web site. This 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.

The PIC16F87/88 belongs to the Mid-Range family of the PICmicro® devices. Block diagrams of the devices are shown in Figure 1-1 and Figure 1-2. These devices contain features that are new to the PIC16 product line:

- Low-power modes: RC_RUN allows the core and peripherals to be clocked from the INTRC, while SEC_RUN allows the core and peripherals to be clocked from the low-power Timer1. Refer to **Section 4.7 "Power-Managed Modes"** for further details.
- Internal RC oscillator with eight selectable frequencies, including 31.25 kHz, 125 kHz, 250 kHz, 500 kHz, 1 MHz, 2 MHz, 4 MHz and 8 MHz. The INTRC can be configured as a primary or secondary clock source. Refer to **Section 4.5 "Internal Oscillator Block"** for further details.
- The Timer1 module current consumption has been greatly reduced from 20 µA (previous PIC16 devices) to 1.8 µA typical (32 kHz at 2V), which is ideal for real-time clock applications. Refer to **Section 7.0 "Timer1 Module"** for further details.
- Extended Watchdog Timer (WDT) that can have a programmable period from 1 ms to 268s. The WDT has its own 16-bit prescaler. Refer to **Section 15.12 "Watchdog Timer (WDT)"** for further details.
- Two-Speed Start-up: When the oscillator is configured for LP, XT or HS Oscillator mode, this feature will clock the device from the INTRC while the oscillator is warming up. This, in turn, will enable almost immediate code execution. Refer to **Section 15.12.3 "Two-Speed Clock Start-up Mode"** for further details.
- Fail-Safe Clock Monitor: This feature will allow the device to continue operation if the primary or secondary clock source fails by switching over to the INTRC.
- The A/D module has a new register for PIC16 devices named ANSEL. This register allows easier configuration of analog or digital I/O pins.

TABLE 1-1: AVAILABLE MEMORY IN PIC16F87/88 DEVICES

Device	Program Flash	Data Memory	Data EEPROM
PIC16F87/88	4K x 14	368 x 8	256 x 8

There are 16 I/O pins that are user configurable on a pin-to-pin basis. Some pins are multiplexed with other device functions. These functions include:

- External Interrupt
- Change on PORTB Interrupt
- Timer0 Clock Input
- Low-Power Timer1 Clock/Oscillator
- Capture/Compare/PWM
- 10-bit, 7-channel A/D Converter (PIC16F88 only)
- SPI™/I²C™
- Two Analog Comparators
- AUSART
- $\overline{\text{MCLR}}$ (RA5) can be configured as an input

Table 1-2 details the pinout of the devices with descriptions and details for each pin.

18.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Ambient temperature under bias	-40°C to +125°C
Storage temperature	-65°C to +150°C
Voltage on any pin with respect to V_{SS} (except V_{DD} and $\overline{MCLR}$)	-0.3V to (V_{DD} + 0.3V)
Voltage on V_{DD} with respect to V_{SS}	-0.3 to +7.5V
Voltage on $\overline{MCLR}$ with respect to V_{SS} **(Note 2)**	-0.3 to +14V
Total power dissipation **(Note 1)**	1W
Maximum current out of V_{SS} pin	200 mA
Maximum current into V_{DD} pin	200 mA
Input clamp current, I_{IK} (V_I < 0 or V_I > V_{DD})	±20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{DD})	±20 mA
Maximum output current sunk by any I/O pin	25 mA
Maximum output current sourced by any I/O pin	25 mA
Maximum current sunk by PORTA	100 mA
Maximum current sourced by PORTA	100 mA
Maximum current sunk by PORTB	100 mA
Maximum current sourced by PORTB	100 mA

Note 1: Power dissipation is calculated as follows: $P_{dis} = V_{DD} \times \{I_{DD} - \sum I_{OH}\} + \sum \{(V_{DD} - V_{OH}) \times I_{OH}\} + \sum(V_{OL} \times I_{OL})$

2: Voltage spikes at the $\overline{MCLR}$ pin may cause latch-up. A series resistor of greater than 1 kΩ should be used to pull $\overline{MCLR}$ to V_{DD}, rather than tying the pin directly to V_{DD}.

† NOTICE: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

APPENDIX F Relevant Information from EasyPIC4 Development Board User Manual

MCU Sockets

The development board has DIP40, DIP28, DIP20, DIP18, DIP14 and DIP8 sockets.
PIC 16F88 used in this project has an 18 Pin packaging body, therefore it was placed into the DIP18 MCU Socket prior to being programmed. All the peripheral devices have parallel connections to the MCU Sockets therefore only one microcontroller was connected to the board at any time [8].

Power Supply

The EasyPIC4 development board has multiple power supply options. It could either be powered up using an external AC or DC voltage supply between 8V and 16V, or it could be powered up using the USB cable connected to a USB port of a computer. The external AC or DC power supply is regulated to a +5V DC supply using an LM7805 voltage regulator installed on the development board. The power supply type is selectable using a jumper JP1. Since the development board had to be connected to a computer for the Microcontrollers to be programmed, the USB was selected as the primary power source and the jumper JP1 was set into its appropriate position.

On-Board USB 2.0 Programmer

The EasyPIC4 development board has a very fast on-board USB2.0 programmer which eliminated the use of specialist programming hardware to be used for programming PIC Microcontrollers. The on-board programmer also resets the MCU after programming it which proved useful during the project as there was no need to reset the MCU. The on-board programmer also proved very useful during the software development and testing phase of the project as microcontrollers could be programmed and tested with newer versions of software code very easily and efficiently whilst plugged into the development board.

Oscillators

The development board has two different oscillators to work with the large number of MCU sockets on the board. Each oscillator was connected to a separate range of MCU sockets. The DIP18 socket has a connection with OSC1 which is an 8 MHz crystal oscillator (supplied with the development board). The oscillator provides the clock signal to the microprocessor while it is plugged in the development board for programming or normal operation.

Push Button Switches & LED's

The EasyPIC4 development board has 36 push buttons, which can be used to change states of digital inputs to the microcontroller's ports. The board also has 36 Light Emitting Diodes

(LED's) which serve the purpose of displaying the pin's digital state. The switches and LED's are connected to the microcontroller's PORTA, PORTB, PORTC, PORTD and PORTE. The groups of LED's for the ports could be enabled/disabled using the DIP switch SW2. The switches could be setup to provide either a 5V or GND (logical 1 or logical 0 respectively) supply to the microcontroller's ports by setting the jumper JP17 to its right position. There is also a RESET push button switch next to JP17 that can be used to RESET the microcontroller. The Push Button Switches and LED's proved very useful during the software testing phase of the project as it was very easy to check or change the state of the microcontroller pins by just checking the LED's and Switches respectively.

LCD 2 x 16 in 4-bit Mode

A 2 x16 LCD could be attached to the EasyPIC4 development board on the LCD pins in the left hand side of the board. The LCD could display two lines of 16 alphanumeric characters, each made up of 5x8 pixels. The LCD was used as data visualization component when the development board was being used as part of the Base Station phase of the project. The Base Station is explained in the later chapters of this report.

RS-232 Communication

RS 232 communication is generally used in point to point data transfer. The EasyPIC4 development board has a RS-232 communication port and a MAX232 voltage converted built into it for voltage conversion. The RS232 port can be used to enable serial data communication microcontroller and a PC. In order to enable RS232 communication a jumper was placed at RC7 for RX line in Jumper Group 7 and a jumper was placed at RB5 for TX in Jumper Group 8. The RS232 communication was very useful during the software testing phase of the project as the board was connected to a PC and the output from the microcontroller was observed at the computer using the hyper terminal window in MikroC programming software.

Direct Port Access

All microcontrollers' input/output pins can be accessed via 10 pin connectors on the right hand side of the EasyPIC4 development board. There are 5 different 10 pin connectors for each of the PORTSA - E of PIC microcontrollers. Each of the 10 pin connectors have two pins for VCC and GND respectively which could be used to power up peripherals connected to the microcontroller. The direct port access option was used during the base station development phase of the project as the RF receiver module was connected to the microcontroller using the PORTC 10-pin set. Further details of the base station are available in the relevant chapters in this report.

All of the information about the different components of the EasyPIC4 development board has been extracted after referring to its user manual [8], which could be consulted for further information.

APPENDIX G Relevant Pages from Micro Tx Transmitter Module Datasheet

The Micro TX is a Type Approved AM radio transmitter module operating at UHF frequencies. It is compatible with both low cost super-regenerative and AM superhet receivers. By providing excellent RF performance in a Type Approved module, the Micro TX minimises design costs and delays. The sub-miniature two-pin package ensures that the module can be fitted into any convenient space on the user's board. This makes it ideally suited to keyfob designs, where space is often limited due to the demand for ever more compact designs.

The unique design (Patent Pending) of this module allows operation on any supply voltage between 2.5 and 13V, simply by changing one external resistor. Users requiring high performance from a compact transmitter will appreciate the efficient operation of the module when driving a tuned loop or short whip antenna. Up to -6 dBm radiated power can be achieved with a 90 mm whip, just over half the length of the usual 1/4 wave antenna. It is compatible with most encoding ICs operating from 3V to 12V.

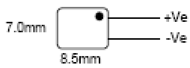
Features

Type Approved to MPT 1340
Ultra-compact two pin package
Wide supply voltage 2.5 to 13 V

Applications

Low cost key-fob designs
Car alarm "blippers"
Garage door openers
Lighting controls

Package Dimensions



Technical Specification

Ambient Temperature 20 ° C

Parameter	Min	Typical	Max	Units
Frequency (UK)	417.925	418.000	418.075	MHz
Frequency (Europe)	433.845	433.920	433.995	MHz
Module voltage	2.2		3.0	Volts
Supply voltage (RD = 100 ohms)	2.5		3.5	Volts
Supply voltage (RD = 2200 ohms)	8.8		13.1	Volts
Input current (mark)	3.0		4.6	mA
Input current (space)		0 mA		
Effective Radiated Power (ERP)		-6dBm		
Maximum baud rate			1200	bps
Range (with suitable receiver)		100		Metres
Dimensions		8.5 x 7.0 x 4.2 +/- 10%		mm
Pin Pitch		5.08		mm
Operating temperature	-10		+40	deg. C
Storage Temperature	-40		+85	deg. C
Patent Pending				

LPRS Data Sheet **Micro Tx Transmitter Module**

Fig.1 Application Circuits

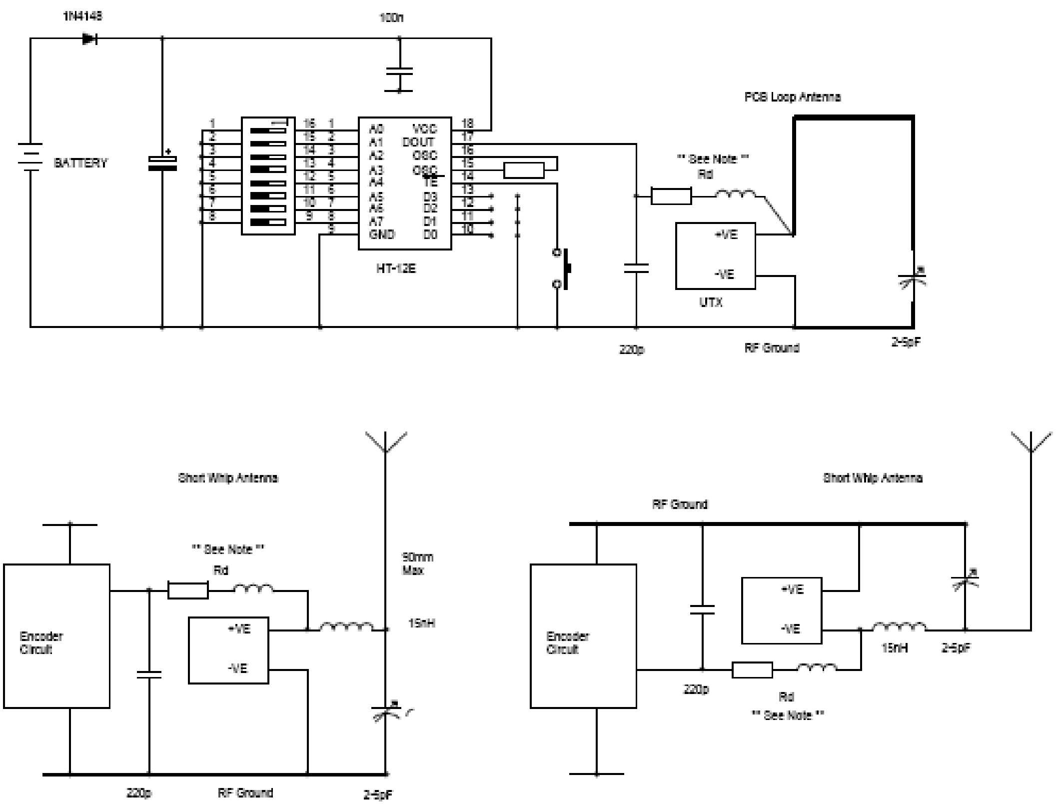
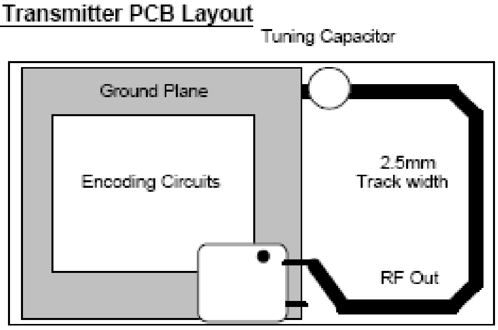


Fig.2 Typical Tuned Loop Transmitter PCB Layout



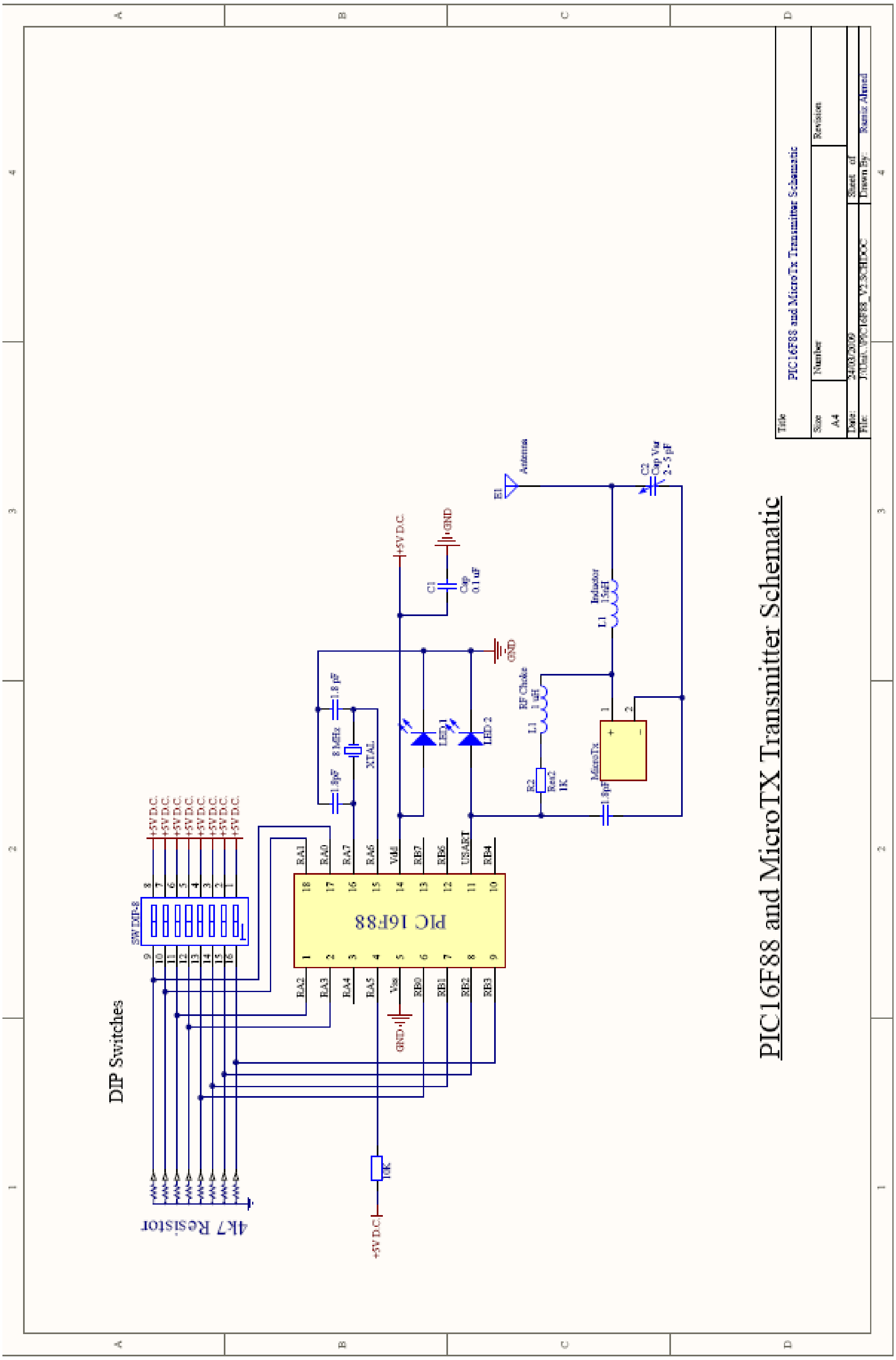
Notes

The Transmitter module should ideally be placed over the ground plane as shown. The loop aerial should be completely clear of the ground plane and all other components. Do not place other components within the loop area.

For operation at low voltages (<3V) a 100uH RF choke should be placed in series with Rd. This minimises RF energy being absorbed by low impedance drive circuitry.

A variable tuning capacitor is preferable to one, or two fixed capacitors in series, if maximum output power is required for all production transmitters. This allows for various tolerances in the device.

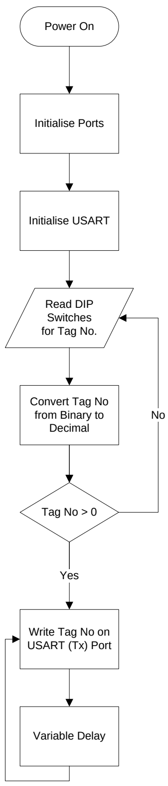
APPENDIX H Radio Tag Circuit Schematic



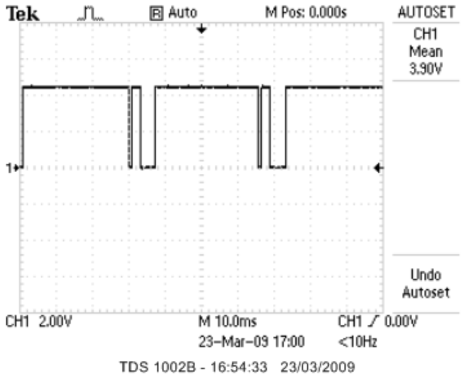
APPENDIX I Radio Tag Software Code & Data Flow Diagram

```
/****************************************************************************
Radio Tag For Item Tracking
Transmitter Side Code V2
Name: Ramiz Ahmed (DSCE 4)
Supervisor: Mohammed Jamro
BEng Digital Systems & Computer Engineering
****************************************************************************/
float dt;
float t;
unsigned char TagNo = 0;
/*~*~*~*~*~*~*~*~*~*~*~*~*~~*~*~*~*~*~ Main Program *~*~*~*~*~*~*~~*~*~*~*~*~*~*~*/
void main() {

ANSEL = 0x00;
INTCON = 0x00;
PORTA=0x00;              // Initialize Port A at Logical Zero
PORTB=0x00;              // Initialize Port B at Logical Zero
TRISA = 0b00001111;      // Initialize Port A0-A3 as Inputs/A4-A7 as Ouputs
TRISB = 0b00001111;      // Initialize Port B0-B3 as Inputs/B4-B7 as Ouputs

USART_init(1200);        // USART intiliazed @ Baud Rate of MicroTx (1200 bps)

dt = 500;
t = dt/2 + (rand()%100);// Mod of a Random Number to Create a Variable Delay
//delay_ms(1000);
while(1)
{
TagNo = (PORTB << 4) | (PORTA & 0x0f); // BitMasking PortA & B Store in TAgNO
if (TagNo > 0)           // Condition - TagNo=0 Not Transmitted
{
USART_Write(TagNo);      // Put TagNo on RB5 (Tx) Pin through USART
vdelay_ms(t);        // USe the variable delay as delay in transmission
}
}
}
```

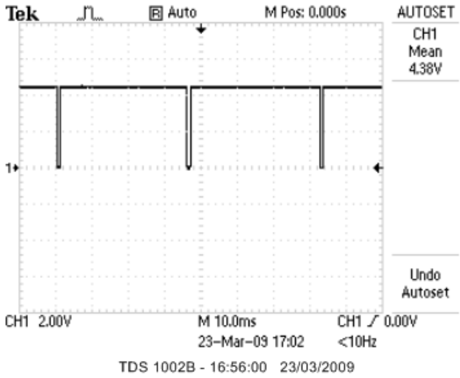
Data Flow Diagram



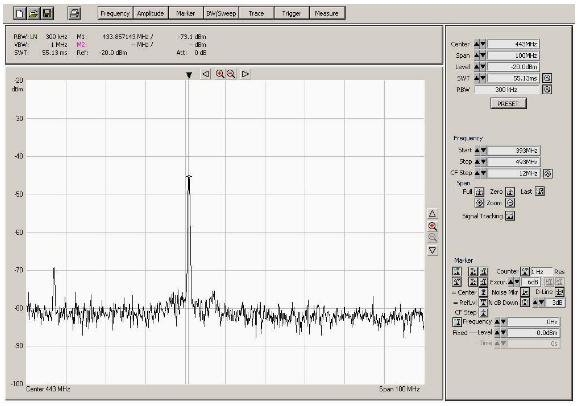
APPENDIX J Radio Tag Testing Results



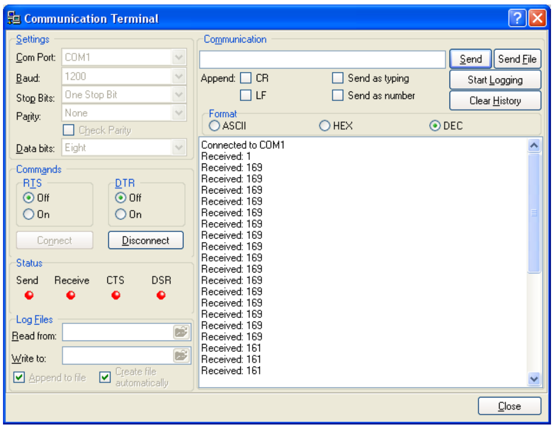
Tag Output @ Tag Serial Number 7



Tag Output @ Tag Serial Number 255



Network Analyzer Output Waveform @ Tag no 3



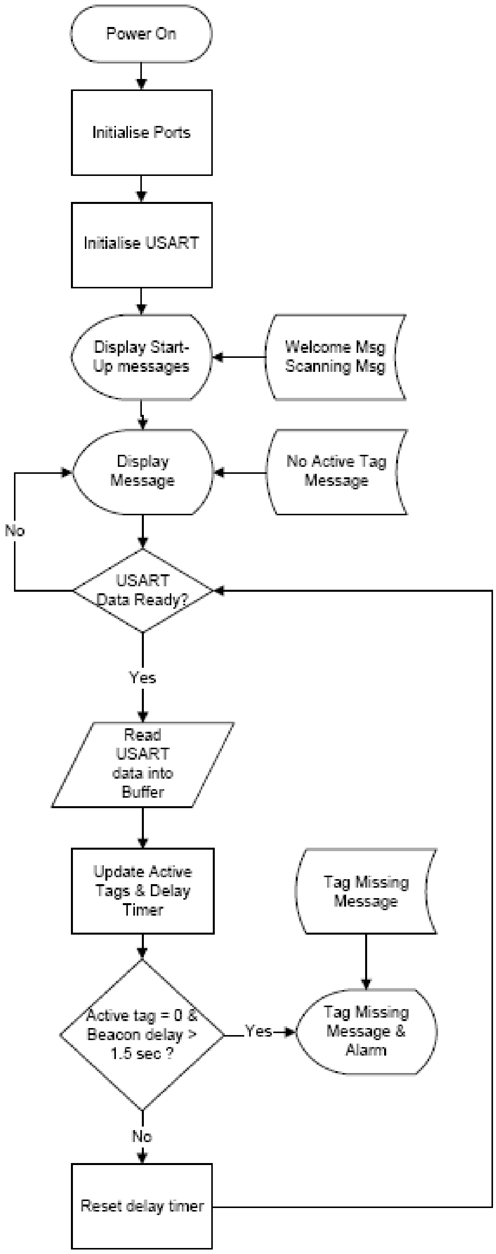
USART Terminal Output during Radio Tag Software Testing

APPENDIX K Base Station Software Code and Data Flow Chart

```
/****************************************************************************
* Radio Tag For Item Tracking                                               *
* (Base Station Code)                                                       *
*****************************************************************************
* Filename: Tag_Rx.c                                                        *
* Date: 04/03/09                                                            *
* File Version: 3.0                                                         *
* Compiler: MikroC Compiler                                                 *
* Programmer: Ramiz AHmed                                                   *
* Course: (BEng) Digital Systems & Computer Engineering                     *
**************************** Variables ****************************************/
//char *text0 = "Tag ";
//char *text1 = "Tracker";
//char *text2 = "Active";
//char *text3 = "Tag";
//char *text4 = "Missing";
#define buffer_length    35

int rx_buffer[buffer_length];
int tag_lookup[3][2];
int column = 0;
int row    = 0;
char tag_temp[4];
int g;
int i;
int j;

int tag_array [3][2] ={{1,0}, {2,0}, {3,0}};
/*************************** Functions ****************************************/
void pic_setup();         // Initialise Port & USART Values for PIC
void welcome_msg();       // Displays a Welcome Message on Power Up
void scan_msg();          // Displays Message Before Scanning for Tags
void no_tag();            // Displays Message if No Active Tags
void clear_buffer();      // Clear the Receive Buffer
void ser_rx(void);        // Receive the Data from the Receive Port
void disp_tag_active(int number); // Display What Tags are active
void disp_tag_missing() ;         // Display if a Tag Goes Missing
/****************************************************************************
                           Define Functions
*****************************************************************************/
void pic_setup()
{
     Usart_init(1200);  //Initialise Usart @ 1200 Baudrate, 8 Bit, No Parity Bit
     TRISB.F7 = 0;
     Portb.F7 = 0;
     TRISD = 0x00;
     Lcd_init(&PortD);
     clear_buffer();
}
/*************************** Clear Buffer **********************************/
void clear_buffer()
{
 for(g=0;g<= buffer_length; g++)
     { rx_buffer[g] = 0; }
}

/*************************** Welcome Message ************************************/
void welcome_msg()
{
Lcd_Cmd(Lcd_CLEAR);
Lcd_Cmd(Lcd_CURSOR_OFF);
Lcd_out(1,1,"Univ of Herts");
Lcd_out(2,1,"Tag Tracker");  // 2 x 16 LCD
//Lcd_out(1,1,"Tag Trac");   // 1 x 16 LCD
//Lcd_out(2,1,"ker");        // 1 x 16 LCD
delay_ms(1000);
}
/**************************** Tag Scan Message *********************************/
void scan_msg()
{
```

```
Lcd_Cmd(Lcd_CLEAR);
Lcd_out(1,1,"Scanning For Tag");
delay_ms(500);
}
/**************************** NO Tag Message **********************************/
void no_tag()
{
Lcd_Cmd(Lcd_CLEAR);
Lcd_out(1,1,"No Active Tags");
delay_ms(500);
}
/**************************** Tag Active Message ******************************/
void disp_tag_active(int number)
{
Lcd_Cmd(Lcd_CLEAR);
Lcd_Cmd(Lcd_CURSOR_OFF);
byteToStr(number,tag_temp);
// First Tag Line
Lcd_out(1,1,"Tag");
Lcd_out(1,4,tag_temp);
Lcd_out(1,9,"Active");
delay_ms(100);
// Second Tag Line
}
/*************************** Tag Missing Message  *****************************/
void disp_tag_missing()
{
Lcd_Cmd(Lcd_CLEAR);
Lcd_Cmd(Lcd_CURSOR_OFF);

Lcd_out(1,1,"Tag");
Lcd_out(1,5,tag_temp);
Lcd_out(1,9,"Active");
// Second Tag Line
}
/*******************************************************************************/


void main(){
//ANSEL = 0x00;

pic_setup();
welcome_msg();
scan_msg();

do{
while(!Usart_data_ready())    // If no Data on USART - Display No Tags & Sound Alarm
{
no_tag();
portb.f7 = 1;
lcd_cmd(lcd_clear);
clear_buffer();
}

if (USART_Data_Ready())              // Keep looping until no more chars
{
Portb.F7 = 0;
for(i=0;i<1;i++)
{
rx_buffer[i] = USART_Read(); // put char in element & then increment index
disp_tag_active(rx_buffer[i]);
}

}
}while(1);
}
```

Receiver Basic Data Flow Chart



Flow Chart Version V1

APPENDIX L Colander Vero Board

Prototyping boards

Veroboard pattern with colander ground plane

Similar in use to the standard Veroboard pattern but offering the advantages of full 0V colander ground plane to provide maximum screening on the component side of the board.

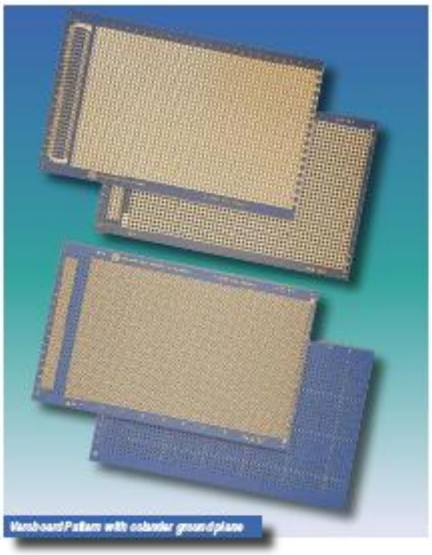
Features

- DIN 41494 cardframe compatible and DIN 41612 connector pattern up to 96/96 ways
- Ideal for hard wiring of discrete components
- Colander ground plane for maximum screening
- Microbus backplane compatible

Veroboard pattern, with colander ground plane — Ordering information

Board dims.	Tracks	Holes/tracks	Base material	Order code
100 x 160	34	54	Epoxy glass	03-2998

Note: Hole grid 2,54 x 2,54mm, hole dia. 1,02mm and 3,81mm gap on double height boards



Veroboard Pattern with colander ground plane

Square pad board

A range of boards offering total flexibility and maximum density of wirewrapped circuitry. Any size of wirewrapping DIP socket or terminal pin can be accepted in either X or Y planes. Vcc and 0V rails may be daisy chained from post to post around the board eliminating the need to stake pins in power rails as on other types of board.

Features

- Maximum packing density
- Total flexibility using hard wire or wirewrapping techniques
- DIN 41494 cardframe compatible and DIN 41612 connector pattern up to 96/96 ways
- Grid references to both sides of board to aid component layout and to assist wiring
- Microbus backplane compatible

Note: Component grids compatible with connectors. Board 03-0111L has a full board pattern aligned with the lower connector giving a 1,27mm offset between the top and bottom connector patterns.

Square pad board — Ordering information

Board dimensions	No. of Pads width	No. of Pads length	Base material	Order code
100 x160	34	54	Epoxy glass	03-0026
100 x 220	34	77	Epoxy glass	03-27555
233,4 x 160	85	52	Epoxy glass	03-0111
233,4 x 160	86	52	Epoxy glass	03-27556*
233,4 x 220	86	75	Epoxy glass	03-27557*

*Note: Hole grid 2,54 x 2,54mm Hole dia. 1,02mm *3,81mm gap on these boards*

Square pad board with colander ground plane

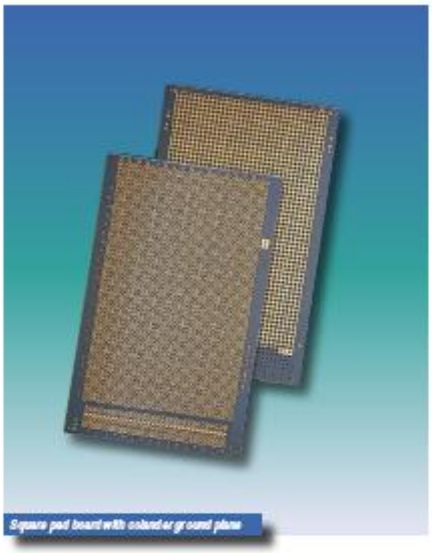
A single height Eurocard similar to the standard square pad board but offering the additional advantage of 0V colander ground plane.

Features

- Maximum packing density
- Total flexibility using hard wire or wire wrapping techniques
- Colander ground plane for maximum screening
- DIN 41494 cardframe compatible and DIN 41612 connector pattern up to 96/96 ways
- Grid references to both sides of board to aid component layout and to assist wiring
- Microbus backplane compatible

Square pad board with colander ground plane — Ordering information

Board dimensions	No. of Pads width	No. of Pads length	Base material	Order code
100 x 160	34	54	Epoxy glass	03-2989



Square pad board with colander ground plane

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APPENDIX M Relevant Pages from PIC 16F877A Datasheet

MICROCHIP

PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

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 other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

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
- 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 $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (VREF) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

CMOS Technology:

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low-power consumption

Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I²C			
PIC16F873A	7.2K	4096	192	128	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2/1	2
PIC16F876A	14.3K	8192	368	256	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

 DS39582B-page 1

17.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Ambient temperature under bias .... -55 to +125°C
Storage temperature .... -65°C to +150°C
Voltage on any pin with respect to V_{SS} (except V_{DD}, $\overline{MCLR}$, and RA4) .... -0.3V to (V_{DD} + 0.3V)
Voltage on V_{DD} with respect to V_{SS} .... -0.3 to +7.5V
Voltage on $\overline{MCLR}$ with respect to V_{SS} **(Note 2)** .... 0 to +14V
Voltage on RA4 with respect to Vss .... 0 to +8.5V
Total power dissipation **(Note 1)** 1.0W
Maximum current out of V_{SS} pin .... 300 mA
Maximum current into V_{DD} pin .... 250 mA
Input clamp current, I_{IK} (V_I < 0 or V_I > V_{DD}) .... ± 20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{DD}) .... ± 20 mA
Maximum output current sunk by any I/O pin .... 25 mA
Maximum output current sourced by any I/O pin .... 25 mA
Maximum current sunk by PORTA, PORTB and PORTE (combined) **(Note 3)** .... 200 mA
Maximum current sourced by PORTA, PORTB and PORTE (combined) **(Note 3)** .... 200 mA
Maximum current sunk by PORTC and PORTD (combined) **(Note 3)** .... 200 mA
Maximum current sourced by PORTC and PORTD (combined) **(Note 3)** .... 200 mA

Note 1: Power dissipation is calculated as follows: $P_{dis} = V_{DD} \times \{I_{DD} - \sum I_{OH}\} + \sum \{(V_{DD} - V_{OH}) \times I_{OH}\} + \sum(V_{OI} \times I_{OL})$

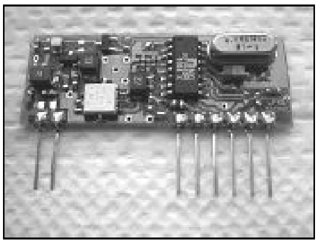
2: Voltage spikes below V_{SS} at the $\overline{MCLR}$ pin, inducing currents greater than 80 mA, may cause latch-up. Thus, a series resistor of 50-100Ω should be used when applying a "low" level to the $\overline{MCLR}$ pin rather than pulling this pin directly to V_{SS}.

3: PORTD and PORTE are not implemented on PIC16F873A/876A devices.

† NOTICE: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

APPENDIX N Relevant Pages from AM2000 RX 433 Receiver Module

This AM superhet receiver provides greatly improved sensitivity and rejection of out of band signals over super regenerative receivers. It is ideal for upgrading car alarm, domestic alarm or other low cost applications that require improved range and more consistent operation. Low radiated emissions ensure compliance with EMC requirements. The receiver operates from a single 5V supply and is pin compatible with many industry standard devices. It is available for operation on 418MHz, 433MHz and 868MHz.

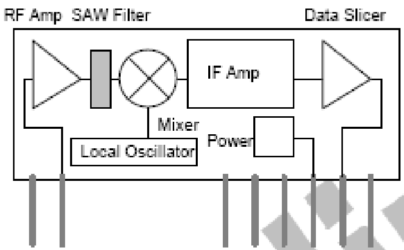


Features

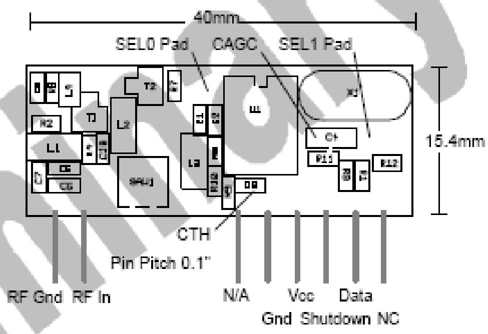
SAW based Front End Filter for selectivity
Crystal controlled synthesiser
Shutdown Input and wakeup output
Duty cycle power saving possible
Small size PCB Mounting, Single-in-Line (SIL) style

Applications

Car alarm receivers
Domestic alarm receivers
Garage door openers
Pager receivers



Block Diagram



Mechanical Detail

Notes

- Gnd and RF Gnd must be connected to 0V earth plane on the mother board.
- NC Pins are No electrical Connection
- The shutdown pin must be pulled down to Gnd to enable the module.

Pin	Function
1	RF Gnd
2	RF In
9	N/A
10	Gnd
11	Vcc
12	Shutdown
13	Data Out
14	NC

Application

The AM2000 series receiver is simple to apply, requiring only a "clean" DC supply of 5 Volts, an antenna and a suitable device for decoding the incoming digital data. The ground pins should be connected to a substantial copper area that will act as a "ground plane". The receiver and its antenna must be kept well away from any circuitry that may generate harmonics that could extend into the UHF region. Even a simple crystal oscillator on a microprocessor clock can do this ! Particularly troublesome are externally bussed microprocessors and switched mode power supplies that can radiate significant energy into the ether. Good EMC practice (and testing) will reduce this likelihood which will generally manifest itself as reduced range or lack of sensitivity.

Antenna

All transmitters and receivers require antennas in order to work efficiently, the AM2000 receiver is no exception to this law of physics ! A ¼ wave whip antenna (approximately 16cm) will provide the best performance. It should be mounted in "free space" and well away from any conductive objects or surfaces.

Absolute Maximum Ratings

Supply Voltage Vcc, Pin 11	0.3 to +5.25 Volts
Operating Temperature	0° C to +70° C (Commercial)
Storage temperature	-10° C to +85° C

Performance Data Supply +5.0 Volt ± 5%, Temperature 20° C

Parameter	Min	Typical	Max	Units	Notes
Supply Voltage	4.75	5.0	5.25	Volts	
Receive frequency (fo)		418.00		MHz	UK only
Receive frequency (fo)		433.92		MHz	UK & Europe
Receive frequency (fo)		868.350		MHz	UK & Europe
Sensitivity for 6dB S/N		-103		dBm	418/433 MHz version
Sensitivity for 6dB S/N		-90		dBm	868 MHz version
RF Pass Band		TBA		kHz	Note 1
LF Pass Band	50 Hz	1.25	25	kHz	Note 2
Supply Current		8		mA	Note 3
Shutdown Current		25		uA	To be characterised
Data output (logic 0)	0		0.5	Volts	50k load
(logic 1)	4.5			Volts	50k load
Size		40 x 15.4		mm	

Notes

1. A low noise amplifier (LNA) and SAW filter provide additional RF selectivity.
2. The bandwidth selectors are by default set to SEL0 low and SEL1 Low.
3. The shutdown pin must be pulled down to Gnd to enable the module.

NB: The module is fitted with an internal 10K pull down resistor to ensure that if the Shutdown pin is left 'floating' the module will be enabled. This has the undesirable effect of increasing the shutdown current by 500uA when it is pulled up to the positive supply ! This resistor should therefore be removed from the board if the shutdown facility is being utilised. Modules can be supplied without this resistor fitted by special request.

Bandwidth Selection

The bandwidth of the demodulator can be configured by 'solder blob' PCB pads on the track side of the PCB. (See Mechanical drawing for location) .During manufacture these jumpers are set to SEL0 Low (0) and SEL1 Low (0).

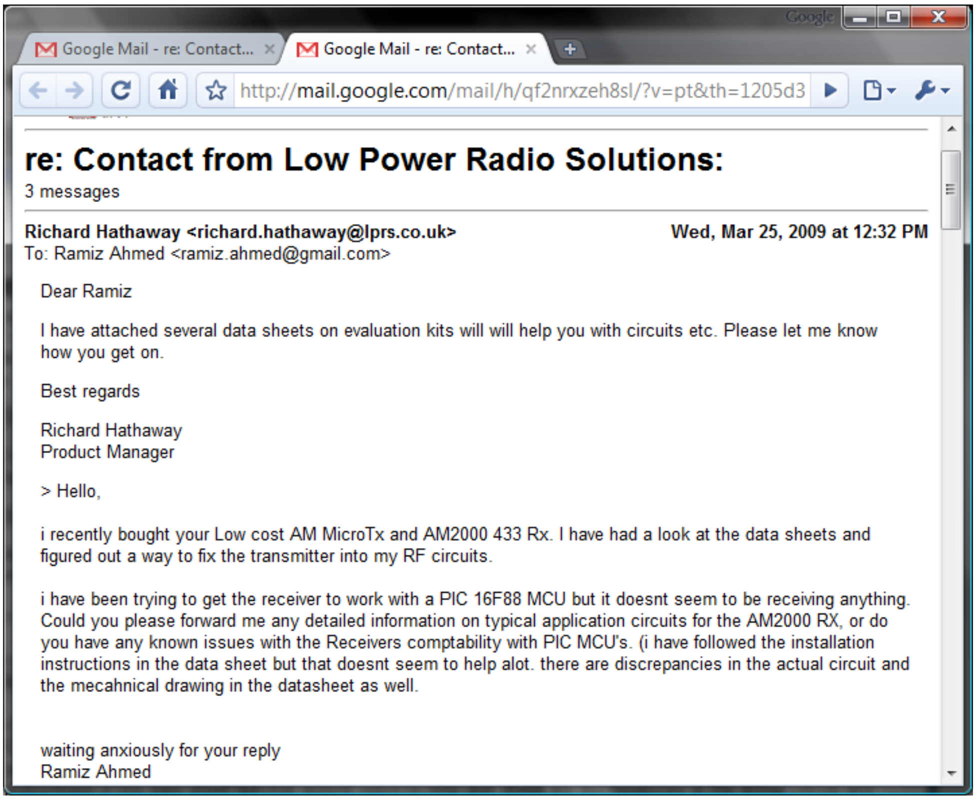
SEL0	SEL1	Bandwidth kHz
0	0	1.25
1	0	2.5
0	1	5
1	1	10

Users should configure these jumpers to reflect the data rate being used for encoding/decoding.

Shutdown Input

The 'shutdown' input can be used to reduce system power consumption by 'duty cycling' the receiver for power critical applications such as battery powered pager receivers.. An internal pull-up resistor is provided on the module and this pin should normally be pulled down to ground to enable the module.

APPENDIX O Email Correspondence with LPRS about AM2000 Receiver Module



Google Mail - re: Contact... Google Mail - re: Contact...

http://mail.google.com/mail/h/qf2nrxzeh8sl/?v=pt&th=1205d3

re: Contact from Low Power Radio Solutions:

3 messages

Richard Hathaway <richard.hathaway@lprs.co.uk> **Wed, Mar 25, 2009 at 12:32 PM**
To: Ramiz Ahmed <ramiz.ahmed@gmail.com>

Dear Ramiz

I have attached several data sheets on evaluation kits will will help you with circuits etc. Please let me know how you get on.

Best regards

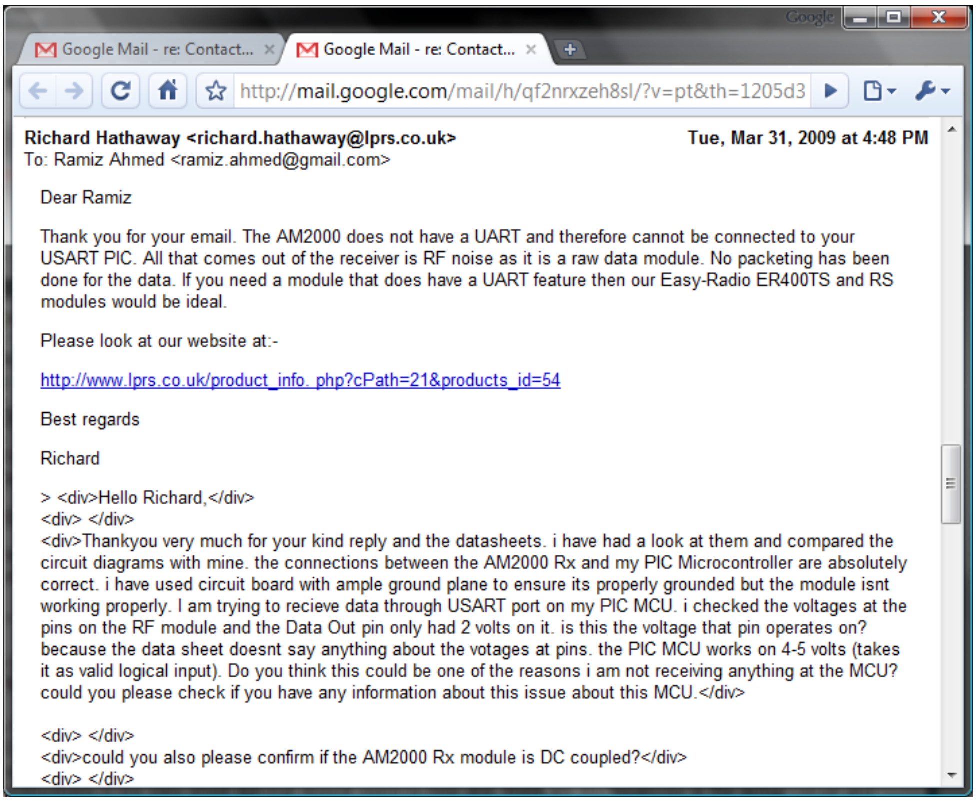
Richard Hathaway
Product Manager

> Hello,

i recently bought your Low cost AM MicroTx and AM2000 433 Rx. I have had a look at the data sheets and figured out a way to fix the transmitter into my RF circuits.

i have been trying to get the receiver to work with a PIC 16F88 MCU but it doesnt seem to be receiving anything. Could you please forward me any detailed information on typical application circuits for the AM2000 RX, or do you have any known issues with the Receivers comptability with PIC MCU's. (i have followed the installation instructions in the data sheet but that doesnt seem to help alot. there are discrepancies in the actual circuit and the mecahnical drawing in the datasheet as well.

waiting anxiously for your reply
Ramiz Ahmed



Google Mail - re: Contact... Google Mail - re: Contact...

http://mail.google.com/mail/h/qf2nrxzeh8sl/?v=pt&th=1205d3

Richard Hathaway <richard.hathaway@lprs.co.uk> **Tue, Mar 31, 2009 at 4:48 PM**
To: Ramiz Ahmed <ramiz.ahmed@gmail.com>

Dear Ramiz

Thank you for your email. The AM2000 does not have a UART and therefore cannot be connected to your USART PIC. All that comes out of the receiver is RF noise as it is a raw data module. No packeting has been done for the data. If you need a module that does have a UART feature then our Easy-Radio ER400TS and RS modules would be ideal.

Please look at our website at:-

http://www.lprs.co.uk/product_info. php?cPath=21&products_id=54

Best regards

Richard

> <div>Hello Richard,</div>
<div> </div>
<div>Thankyou very much for your kind reply and the datasheets. i have had a look at them and compared the circuit diagrams with mine. the connections between the AM2000 Rx and my PIC Microcontroller are absolutely correct. i have used circuit board with ample ground plane to ensure its properly grounded but the module isnt working properly. I am trying to recieve data through USART port on my PIC MCU. i checked the voltages at the pins on the RF module and the Data Out pin only had 2 volts on it. is this the voltage that pin operates on? because the data sheet doesnt say anything about the votages at pins. the PIC MCU works on 4-5 volts (takes it as valid logical input). Do you think this could be one of the reasons i am not receiving anything at the MCU? could you please check if you have any information about this issue about this MCU.</div>

<div> </div>
<div>could you also please confirm if the AM2000 Rx module is DC coupled?</div>
<div> </div>