CHAPTER 1

INTRODUCTION

TO

PIC MICROCONTROLLERS

ABSTRACT

This is an introductory chapter that deals with the introduction to microcontrollers. Further it also deals with choosing of PIC microcontroller.
1.1 Review on Evolution of Microprocessors

In 1969, Bob Noyce and Gordon Moore have set up the Intel Corporation to manufacture memory chips for the mainframe computer industry [1]. Later in 1971, the first microprocessor chip 4040 was manufactured by Intel. These were basically designed for a calculator named Busicom which was one of the first portable calculators. This was a very simple calculator which could only add and subtract numbers, 4 bits at a time. 4040 chip was so successful that it was soon followed by Intel’s 8-bit 8008 microprocessor. This was a simple microprocessor with limited resources, poorly implemented interrupt mechanisms, and multiplexed address and data buses. The first really powerful 8-bit microprocessor appeared in early 1974 as Intel 8080 chip. This microprocessor had separate address and data buses with 64K byte of address space which was enormous in 1975 standards. 8080 microprocessor was the first microprocessor used in homes as a personal computer named Altair. 8080 has been a very successful microprocessor but soon other companies' began producing microprocessor chips. Motorola introduced the 8080 but has also been very popular.

In 1976, Zilog introduced the Z80 microprocessor which was much more advanced than the 8080. The instruction set of Z80 was downward compatible with the 8080 and this made Z80 to be one of the most successful microprocessors of that time [2]. Z80 was used in many microprocessor based applications, including home computers and games consoles. Again in 1975, Intel introduced an enhanced version of 8080, the 8085 processor (NMOS), which is the most popular and powerful 8-bit processor being in use now-a-days also. Some examples of 8-bit microprocessors from other companies are Zilogs Z80, and Z8000, National semiconductors NSC800, Motorola MC6800, Rockwell’s PPS-4 etc. The 8-bit microprocessors were followed by microprocessors operating on 12-bit, 16-bit, 32-bit, 64-bit
respectively [3]. A few of the important microprocessors from Intel family are 80286, 80386, and 80486 followed by Pentium, Pentium pro, and Pentium 2, Pentium 3 etc. Also a number of 64-bit processors such as SUNs SPARC, R 12000 etc. have been developed by different companies. In 1976, Motorola created a microprocessor chip required to make a complete computer system. This was a major step in the evolution of the microcontrollers which are basically computers consisting of only one chip. In later years, we see many other microcontroller chips in the market, such as Intel 8048, 8049, Motorola 6809, Atmel 89C51, etc.

1.1.1 Introduction to Microcontroller

A microcontroller is a small computer on a single integrated circuit containing a processor core, memory and programmable input/output peripherals. Neither program memory in the form of NOR flash or OTP ROM is also include on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems.

The smallest microcontroller has only eight pins but some having 68 pins are also being marketed. In the last five years, the prices of microcontrollers have dropped by 80% and are now one of the most cost-effective components in Industry. Being software-driven; microcontrollers greatly simplify the design of sophisticated Instrumentation and control circuitry [4].
The movement of the last two decades toward more ubiquitous computing systems will continue and embedded systems will become even more prominent in every aspect of technology and life.

By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digital control even more devices and processes.

Microcontrollers usually contain from several to dozens of general purpose input/output (GPIO). GPIO pins are software configurable to either an input or an output state. When GPIO pins are configured to an input state, they are used to read sensors (or) external signals. Configured to the output state, GPIO pins can drive external devices such as LEDs, LCDs or motors.

Many embedded systems need to read sensors that produce analog signals. For this purpose microcontroller has ADC (Analog-to-digital converter). A less common feature on some microcontroller is a digital-to-analog converter (DAC) that allows the processor to output analog signals or voltage levels.

In addition to the converters, many embedded microcontrollers include a variety of timers as well. One of the most common types of timers is the programmable Interval Timer (PIT).

In microcontroller a dedicated block (PWM) pulse width Modulation makes it possible for the CPU to control power converters, resistive loads, motors, etc. UART (Universal Asynchronous Receiver/transmitter) block makes it possible to receive and transmit data over serial line. Dedicated on-chip hardware also often includes capabilities to communicate with other devices in digital formats such as I2C and SPI (Serial Peripheral Interface).
1.1.2 Different Microcontrollers Architectures and Vendors

There are several dozen microcontroller architectures and Vendors.

1) ARM core processors (many vendors) include ARM9, ARM cortex-A8, sitara ARM Microprocessor.

2) Atmel AVR (8-bit), AVR32 (32-bit) and AT91SAM (32-bit).

3) Cypress semiconductors M8C core used in their PSOC (Programmable System-On-Chip).

4) Free scale cold fire (32-bit) and SO8 (8-bit).

5) Free scale 68HC11 (8-bit).

6) Intel 8051.

7) Infineon; 8, 16, 32 bit microcontrollers.


9) NXP semiconductors LPC 1000, LPC 2000, LPC.3000, LPC 4000(32-bit), LPC 900, LPC 700(8-bit).

10) Parallax Propeller.

11) Power PC ISE.
12) Rabbit 2000 (8-bit).

13) RenesasRX, V850, HitactiH8, HitachisuperH (32-bit), M16C (16-bit), RL78, R8C, 78K0/78KOR (8-bit).

14) Silicon Laboratories pipelined 8-bit 8051 microcontrollers and mixed-signal ARM-based 32-bit microcontrollers.

15) STMicroelectronics STM8 (8-bit), ST10 (16-bit) and STM32 (32-bit).

16) Texas Instruments T1 MSP430 (16-bit)

17) Toshiba TLCS-870 (8-bit/16-bit).

The specifications of different microcontrollers from different manufactures are shown in Table 1.1.
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>I/O Pins</th>
<th>Counters</th>
<th>RAM( bytes)</th>
<th>ROM( bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitachi</td>
<td>HMCS40</td>
<td>28:10</td>
<td>-</td>
<td>32</td>
<td>512</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28:23</td>
<td>1</td>
<td>64</td>
<td>1K</td>
</tr>
<tr>
<td>National</td>
<td>COP420</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKI</td>
<td>MSM6411</td>
<td>16:11</td>
<td>-</td>
<td>32</td>
<td>1K</td>
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<td></td>
<td>28:23</td>
<td>-</td>
<td>64</td>
<td>1K</td>
</tr>
<tr>
<td>T1</td>
<td>TMS1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Toshiba</td>
<td>TLS47</td>
<td>42:35</td>
<td>2</td>
<td>128</td>
<td>2K</td>
</tr>
<tr>
<td>Hitachi</td>
<td>H8/532</td>
<td>84:65</td>
<td>5</td>
<td>1K</td>
<td>32K</td>
</tr>
<tr>
<td>Intel</td>
<td>80C196</td>
<td>68:40</td>
<td>2</td>
<td>232</td>
<td>8K</td>
</tr>
<tr>
<td>National</td>
<td>HPC16164</td>
<td>68:52</td>
<td>4</td>
<td>512</td>
<td>16K</td>
</tr>
<tr>
<td>Motorola</td>
<td>68HC11</td>
<td>52:40</td>
<td>2</td>
<td>256</td>
<td>8K</td>
</tr>
<tr>
<td>Rockwell</td>
<td>6500/1</td>
<td>40:32</td>
<td>1</td>
<td>64</td>
<td>2K</td>
</tr>
<tr>
<td>Philips</td>
<td>97C552</td>
<td>68:48</td>
<td>3</td>
<td>256</td>
<td>8K</td>
</tr>
<tr>
<td>Zilog</td>
<td>Z8</td>
<td>40:32</td>
<td>2</td>
<td>128</td>
<td>2K</td>
</tr>
<tr>
<td>Zilog</td>
<td>Z86C83</td>
<td>28:22</td>
<td>2</td>
<td>256</td>
<td>4K</td>
</tr>
<tr>
<td>T1</td>
<td>TMS 7500</td>
<td>40:32</td>
<td>1</td>
<td>128</td>
<td>2K</td>
</tr>
<tr>
<td>T1</td>
<td>TMS 370C050</td>
<td>68:55</td>
<td>2</td>
<td>256</td>
<td>4K</td>
</tr>
<tr>
<td>Microchip</td>
<td>PIC16C56</td>
<td>18:12</td>
<td>0</td>
<td>25</td>
<td>1K</td>
</tr>
<tr>
<td></td>
<td>DS 5000-8</td>
<td>32</td>
<td>-</td>
<td>128</td>
<td>8K</td>
</tr>
</tbody>
</table>

Table 1.1 The specifications of different microcontrollers from different manufacture.
1.2 CHOOSING OF PIC MICROCONTROLLER

When it comes to choosing microcontrollers for projects, such as electronic projects or electrical projects, there are virtually hundreds of choices today, ranging from 8 bit to 32 bits. But for researchers who begin to research on microcontrollers only a handful of microcontrollers are suitable. The following are the best options given various constraints like cost, complexity, availability and awareness etc [2].

1. Microchips-PIC microcontrollers.
3. ARM Microcontrollers by Texas Instruments.

Each of these options has their own advantage.

1.2.1 INTRODUCTION TO PIC MICROCONTROLLER:

PIC microcontrollers are made by Microchip and as of today they are the world’s most popular microcontroller family. PIC controllers are a very optimum, combination of cost, complexity, features and availability. Especially for beginners who want to learn microcontrollers.

PIC microcontroller is an excellent choice, because they combine perhaps all the features. PICs are an ideal choice not just for electronic projects, but also for electrical projects that require features like PWM for machine control and similar applications.

We, at Ensemble Technologies, have, over the years used dozens of different microcontrollers are the most optimum particularly the PIC 18 family of controllers. Because of PICs are usually the cheapest and with most peripherals and probably there is a lot more resources based around PICs and well supported.
Most of the newer PICs have internal oscillators and PIC uses little power consumption. PICs have less instruction sets with RISC design. Its code is extremely efficient, allowing the PIC to run with typically less program memory than its larger competitors and high clock speed.

A PIC microcontroller plays a useful role in the scenario of embedded information processing. Embedded means “hidden” or buried. The embedded information is truly hidden inside the device/product that is in use.

The earliest microcontrollers used mask ROM to store firmware. Later microcontrollers like PIC microcontrollers had quartz windows that allowed ultra-violet light in to erase the EPROM. The microchip PIC 16C84 introduced in 1993 was the first microcontroller to use EEPROM to store firmware. In 1993 Atmel neither introduced the first microcontroller using nor flash memory to store firmware. Along with the strong line up of current part numbers, the addition of more flash program memory parts, the PIC 18 family architecture and new built-in features will make the PIC micro MCU a strong contender for the foreseeable future [5].

PIC microcontroller architecture is based on a modified Harvard RISC instruction set with dual-bus architecture, providing fast and flexible design with an easy migration path from only 6 pins to 80 pins, and from 384 bytes to 128 bytes of program memory.

1.2.2 Reasons for popularity of PIC microcontrollers
PIC microcontrollers are available with many different specifications depending on:
⇒ Memory type

→ Flash

→ OTP [one-time-programmable]
ROM [Read-only-memory]

ROM less

Input-Output (I/O) pin count

- 4-18 pins
- 20-28 pins
- 32-44 pins
- 45 and above pins

Memory size

- 0.5-1K
- 2-4K
- 8-16K
- 24-32K
- 96-128K

Special Features

- CAN
- USB
- LCD
- Motor control
- Radio Frequency
Although there are many models of PIC microcontrollers, the nice thing is that they are upward compatible with each other and a program developed for one model can vary easily, in many cases with no modifications, be run on other models of the family. The basic assembler instruction set of PIC microcontrollers consists of only 33 instructions and most of the family members use the same instruction set except the newly developed devices. This is why a program developed for one model can run on another model with similar architecture without any changes.

General characteristics of PIC microcontrollers:

- RISC instruction set with only a handful of instructions to learn
- Digital I/O ports
- On-chip timer with 8-bit prescaler
- Power-on –reset
- Watchdog timer
- Power-saving SLEEP mode
- High source and sink current
- Direct, indirect, and relative addressing modes
- External clock interface
- RAM data memory
- EPROM or Flash program memory
Some devices offer the following additional features:

- Analog input channels
- Analog comparators
- Additional timer circuits
- EEPROM data memory
- External and internal interrupts
- Internal oscillator
- Pulse-width modulated (PWM) output
- USART serial interface

Some even more complex devices in the family offer the following additional features:

- CAN bus interface
- I2C bus interface
- SPI bus interface
- Direct LCD interface
- USB interface
- Motor control
Although there are several hundred of PIC microcontrollers, choosing a microcontroller for an application is not a difficult task and requires taking into account these factors:

- Number of I/O pins required
- Required peripherals (USART, USB)
- The minimum size of program memory
- The minimum size of RAM
- Speed
- Physical size
- Cost

There are several hundred models of PIC microcontrollers, the family can be broken down into three main groups, which are

- 12-bit instruction word (12C5XX, 16C5XX) also called as 12 series
- 14-bit instruction word (16F8X, 16F87X) also called as 16 series
- 16-bit instruction word (17C7XX, 18C2XX) also called as 17 series and 18 series

All three groups share the same RISC architecture and the same instruction set, with a few additional instructions available for the 14-bit models, and many more instructions available for the 16-bit models [6, 7].

1.2.3 Different families of PIC microcontroller

There are different families of PIC microcontrollers. They are classified as shown below:

- Base- Line 8-bit Architecture (12-bit Instruction word Length)
- Mid- Range 8-bit Architecture (14-bit Instruction word Length)
- High- End 8-bit Architecture (16-bit Instruction word Length)

Microcontrollers belonging to the above class are shown in Table 1.2, 1.3, 1.4, respectively.
<table>
<thead>
<tr>
<th>Family</th>
<th>RAM Kbytes</th>
<th>ROM Bytes</th>
<th>Pins</th>
<th>Clock Freq MHz</th>
<th>A/D Inputs</th>
<th>Resolution Of A/D converter</th>
<th>Comparators</th>
<th>8/16 Bit Timers</th>
<th>Serial communication</th>
<th>PWM outputs</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC10</td>
<td>0.375-0.75</td>
<td>16-24</td>
<td>6-8</td>
<td>4-8</td>
<td>0-2</td>
<td>8</td>
<td>0-1</td>
<td>1X8</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PIC12</td>
<td>0.75-1.5</td>
<td>25-38</td>
<td>8</td>
<td>4-8</td>
<td>0-3</td>
<td>8</td>
<td>0-1</td>
<td>1X8</td>
<td>-</td>
<td>-</td>
<td>EEPROM</td>
</tr>
<tr>
<td>PIC16</td>
<td>0.75-3</td>
<td>25-134</td>
<td>14-44</td>
<td>20</td>
<td>0-3</td>
<td>8</td>
<td>0-2</td>
<td>1X8</td>
<td>-</td>
<td>-</td>
<td>EEPROM</td>
</tr>
<tr>
<td>PIC16</td>
<td>1.5</td>
<td>25</td>
<td>18-20</td>
<td>20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1X8</td>
<td>-</td>
<td>-</td>
<td>Vdd=15V</td>
</tr>
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Table 1.2 Base-Line 8-bit Architecture, 12-bit Instruction word Length
<table>
<thead>
<tr>
<th>Family</th>
<th>RAM Kbytes</th>
<th>ROM Bytes</th>
<th>Pins</th>
<th>Clock Freq MHz</th>
<th>A/D Inputs</th>
<th>Resolution Of A/D converter</th>
<th>Comparators</th>
<th>8/16 Bit Timers</th>
<th>Serial communication</th>
<th>PWM outputs</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC12</td>
<td>1.75-3.5</td>
<td>64-128</td>
<td>8</td>
<td>20</td>
<td>0-4</td>
<td>10</td>
<td>1</td>
<td>1-2X8</td>
<td>USART</td>
<td>-</td>
<td>EEPROM</td>
</tr>
<tr>
<td>FXXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1X16</td>
<td></td>
<td>0-1</td>
<td></td>
</tr>
<tr>
<td>PIC12</td>
<td>1.75</td>
<td>64</td>
<td>8</td>
<td>20</td>
<td>0-4</td>
<td>10</td>
<td>1</td>
<td>1-2X8</td>
<td>USART</td>
<td>-</td>
<td>0-1</td>
</tr>
<tr>
<td>HVX</td>
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<td></td>
<td></td>
<td>1X16</td>
<td></td>
<td>0-1</td>
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</tr>
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</tr>
<tr>
<td>PIC16</td>
<td>1.75-14</td>
<td>64-368</td>
<td>14-64</td>
<td>20</td>
<td>0-13</td>
<td>8or 10</td>
<td>0-2</td>
<td>1-2X8</td>
<td>USART</td>
<td>0-1</td>
<td></td>
</tr>
<tr>
<td>FXXX</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1X16</td>
<td>I2C</td>
<td></td>
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</tr>
<tr>
<td>PIC16</td>
<td>1.75-3.5</td>
<td>64-128</td>
<td>14-20</td>
<td>20</td>
<td>0-12</td>
<td>10</td>
<td>2</td>
<td>2X8</td>
<td>USART</td>
<td>-</td>
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<tr>
<td>HVX</td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>SPI</td>
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</tbody>
</table>

Table 1.3 Mid-Range 8-bit Architecture, 14-bit Instruction word Length
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<thead>
<tr>
<th>Family</th>
<th>RAM Kbytes</th>
<th>ROM Bytes</th>
<th>Pins</th>
<th>Clock Freq MHz</th>
<th>A/D Inputs</th>
<th>Resolutio n Of A/D converter</th>
<th>Comparators</th>
<th>8/16 Bit Timers</th>
<th>Serial communicatio n</th>
<th>PWM outputs</th>
<th>Others</th>
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</thead>
<tbody>
<tr>
<td>PIC18 FXXX</td>
<td>4-128</td>
<td>256-3936</td>
<td>18-80</td>
<td>32-48</td>
<td>4-16</td>
<td>10or12</td>
<td>0-3</td>
<td>0-2X8</td>
<td>USB 2.0 CAN 2.0 USART I2C SPI</td>
<td>0-5</td>
<td></td>
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<tr>
<td>PIC18 FXX JXX</td>
<td>8-128</td>
<td>1024-3936</td>
<td>28-100</td>
<td>40-48</td>
<td>10-16</td>
<td>10</td>
<td>2</td>
<td>0-2X8</td>
<td>USB 2.0 ETHERNET USART I2C SPI</td>
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<tr>
<td>PIC18 FXX KXX</td>
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<td>768-3936</td>
<td>28-44</td>
<td>64</td>
<td>10-13</td>
<td>10</td>
<td>2</td>
<td>1X8</td>
<td>USART I2C SPI</td>
<td>2</td>
<td></td>
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</table>

Table 1.4 High-End 8-bit Architecture, 16-bit Instruction word Length
1.3 Conclusion

The introduction presented above gives an idea regarding the role of PIC microcontroller. PIC18F25K20 is chosen in the present work. It is the microcontroller that is used in Amicus 18 module. Before going to know the details of present work it is worthwhile to acquaint with the microcontroller used in the present work.
REFERENCES


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