CHAPTER 1

MICROCOMPUTER SYSTEMS

1.1 Introduction

The term microcomputer is used to describe a system that includes a microprocessor, program memory, data memory, and an input/output (I/O). Some microcomputer systems include additional components such as timers, counters, analogue-to-digital converters and so on. Thus, a microcomputer system can be anything from a large computer system having hard disks, floppy disks and printers, to single chip computer systems.

In this book we are going to consider only the type of microcomputers that consist of a single silicon chip. Such microcomputer systems are also called microcontrollers.

1.2 Microcontroller Evolution

First, microcontrollers were developed in the mid-1970s. These were basically calculator-based processors with small ROM program memories, very limited RAM data memories, and a handful of input/output ports.

As silicon technology developed, more powerful, 8-bit microcontrollers were produced. In addition to their improved instruction sets, these microcontrollers included on-chip counter/timers, interrupt facilities, and improved I/O handling. On-chip memory capacity was still small and was not adequate for many applications. One of the most significant developments at this time was the availability of on-chip ultraviolet erasable EPROM memory. This simplified the product development time considerably and, for the first time, also allowed the use of microcontrollers in low-volume applications.

The 8051 family was introduced in the early 1980s by Intel. Since its introduction, the 8051 has been one of the most popular microcontrollers and has been second-sourced by many manufacturers. The 8051 currently has many different versions and some types include on-chip analogue-to-digital converters, a considerably large size of program and data memories,
pulse-width modulation on outputs, and flash memories that can be erased and reprogrammed by electrical signals.

Microcontrollers have now moved into the 16-bit market. 16-bit microcontrollers are high-performance processors that find applications in real-time and compute intensive fields (e.g. in digital signal processing or real-time control). Some of the 16-bit microcontrollers include large amounts of program and data memories, multi-channel analogue-to-digital converters, a large number of I/O ports, several serial ports, high-speed arithmetic and logic operations, and a powerful instruction set with signal processing capabilities.

1.3 Microcontroller Architecture

The simplest microcontroller architecture consists of a microprocessor, memory, and input/output. The microprocessor consists of a central processing unit (CPU) and the control unit (CU).

The CPU is the brain of a microprocessor and is where all of the arithmetic and logical operations are performed. The control unit controls the internal operations of the microprocessor and sends control signals to other parts of the microprocessor to carry out the required instructions.

Memory is an important part of a microcomputer system. Depending upon the application we can classify memories into two groups: program memory and data memory. Program memory stores all the program code. This memory is usually a read-only memory (ROM). Other types of memories, e.g. EPROM and PEROM flash memories, are used for low-volume applications and also during program development. Data memory is a read/write memory (RAM). In complex applications where there may be need for large amounts of memory it is possible to interface external memory chips to most microcontrollers.

Input/Output (I/O) ports allow external digital signals to be connected to the microcontroller. I/O ports are usually organized into groups of 8 bits and each group is given a name. For example, the 8051 microcontroller contains four 8-bit I/O ports named P0, P1, P2, and P3. On some microcontrollers the direction of the I/O port lines are programmable so that different bits of a port can be programmed as inputs or outputs. Some microcontrollers (including the 8051 family) provide bi-directional I/O ports. Each I/O port line of such microcontrollers can be used as inputs and outputs. Some microcontrollers provide ‘open-drain’ outputs where the output transistors are left floating (e.g. port P0 of the 8051 family). External pull-up resistors are normally used with such output port lines.
1.4 8051 Family

The 8051 family is a popular, industry standard 8-bit single chip microcomputer (microcontroller) family, manufactured by various companies with many different capabilities. The basic standard device, which is the first member of the family, is the 8051, which is a 40-pin microcontroller. This basic device is now available in several configurations. The 80C51 is the low-power CMOS version of the family. The 8751 contains EPROM program memory, used mainly during development work. The 89C51 contains flash programmable and erasable memory (PEROM) where the program memory can be reprogrammed without erasing the chip with ultraviolet light. The 8052 is an enhanced member of the family which contains more RAM and also more timer/counters. There are many versions of the 40-pin family which contain on-chip analogue-to-digital converters, pulse-width modulators, and so on. At the lower end of the 8051 family we have the 20-pin microcontrollers which are code compatible with the 40-pin devices. The 20-pin devices have been manufactured for less complex applications where the I/O requirements are not very high and where less power is required (e.g. in portable applications). The AT89C1051 and AT89C2051 (manufactured by Atmel) are such microcontrollers, which are fully code compatible with the 8051 family and offer reduced power and less functionality. Table 1.1 gives a list of the characteristics of some members of the 8051 family.

<table>
<thead>
<tr>
<th>Device</th>
<th>Program memory</th>
<th>Data memory</th>
<th>Timer/</th>
<th>I/O pins</th>
<th>Pin count</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT89C1051</td>
<td>1K flash</td>
<td>64 RAM</td>
<td>1</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>AT89C2051</td>
<td>2K flash</td>
<td>128 RAM</td>
<td>2</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>AT89C51</td>
<td>4K flash</td>
<td>128 RAM</td>
<td>2</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>AT89C52</td>
<td>8K flash</td>
<td>256 RAM</td>
<td>3</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>8051AH</td>
<td>4K ROM</td>
<td>128 RAM</td>
<td>2</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>87C51H</td>
<td>4K EPROM</td>
<td>128 RAM</td>
<td>2</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>8052AH</td>
<td>8K ROM</td>
<td>256 RAM</td>
<td>3</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>87C52</td>
<td>8K EPROM</td>
<td>256 RAM</td>
<td>3</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>87C54</td>
<td>16K EPROM</td>
<td>256 RAM</td>
<td>3</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>87C58</td>
<td>32K EPROM</td>
<td>256 RAM</td>
<td>3</td>
<td>32</td>
<td>40</td>
</tr>
</tbody>
</table>
In this book all the projects are based upon the AT89C2051 microcontroller. The code given will run on other members of the family, including the 40-pin devices. The reasons for choosing the AT89C2051 are its low cost, low power consumption, small space (20 pin), and powerful features.

In this chapter we shall be looking at the features of the 8051 family briefly with more emphasis on the smaller AT89C2051. More information on these microcontrollers can be obtained from the manufacturers’ data sheets.

1.5 Architecture of the 8051 Family

The 8051 is an 8-bit, low-power, high-performance microcontroller. There are a large number of devices in the 8051 family with similar architecture and each member of the family is downward compatible with each other. The basic 8051 microcontroller has the following features:

- 4 Kbytes of program memory
- 256 x 8 RAM data memory
- 32 programmable I/O lines
- Two 16-bit timer/counters
- Six interrupt sources
- Programmable serial UART port
- External memory interface
- Standard 40-pin package

The EPROM versions of the family (e.g. 8751) are used for development and the program memory of these devices is erased with an ultraviolet light source. The pin configuration of the standard 8051 microcontroller is shown in Fig. 1.1.

The AT89C2051 is a low-end member of the 8051 family, aimed for less complex applications. This device contains a 2 Kbyte flash programmable memory (PEROM) which can be erased and reprogrammed using a suitable programmer. The AT89C2051 contains 128 bytes of RAM and 15 programmable I/O lines. The code developed for this device runs on a standard 8051 without any modification. As shown in Fig. 1.2, the AT89C2051 is housed in a 20-pin package.

1.6 Pin Configuration

Descriptions of the various pins are given below.
This is the reset input. This input should normally be at logic 0. A reset is accomplished by holding the RST pin high for at least two machine cycles. Power-on reset is normally performed by connecting an external capacitor and a resistor to this pin (see Figs 1.3 and 1.4).

**P3.0**
This is a bi-directional I/O pin (bit 0 of port 3) with an internal pull-up resistor. This pin also acts as the data receive input (RXD) when the device is used as an asynchronous UART to receive serial data.
This is a bi-directional I/O pin (bit 1 of port 3) with an internal pull-up resistor. This pin also acts as the data transmit output (TXD) on the 8051 when the device is used as an asynchronous UART to transmit serial data.

**XTAL1 and XTAL2**

These pins are where an external crystal should be connected for the operation of the internal oscillator. Normally two 33 pF capacitors are connected with the crystal as shown in Figs 1.3 and 1.4. A machine cycle is obtained by dividing the crystal frequency by 12. Thus, with a 12 MHz crystal, the machine cycle is 1 μs. Most machine instructions execute in one machine cycle.

This is a bi-directional I/O pin (bit 2 of port 3) with an internal pull-up resistor. This pin is also the external interrupt 0 (INT0) pin.
P3.3

This is a bi-directional I/O pin (bit 3 of port 3) with an internal pull-up resistor. This pin is also the external interrupt 1 (INT1) pin.

P3.4

This is a bi-directional I/O pin (bit 4 of port 3) with an internal pull-up resistor. This pin is also the counter 0 input (T0) pin.
P3.5
This is a bi-directional I/O pin (bit 5 of port 3) with an internal pull-up resistor. This pin is also the counter 1 input (T1) pin.

GND
Ground pin.

P3.6
This is a bi-directional I/O pin. This pin is not available on the AT89C2051. It is also the external memory write (WR) pin.
P3.7
This is a bi-directional I/O pin for bit 7 of port 3. On the standard 8051, this pin is also the external data memory read (RD) pin.

P1.0
This is a bi-directional I/O pin for bit 0 of port 1. This pin has no internal pull-up resistors on the 20-pin devices. It is also used as the positive input of the analogue comparator (AIN0) on the 20-pin device.

P1.1
This is a bi-directional I/O pin for bit 1 of port 1. This pin has no internal pull-up resistors on the 20-pin devices. It is also used as the positive input of the analogue comparator (AIN1) on the 20-pin device.

P1.2 to P1.7
These are the remaining bi-directional I/O pins of port 1. These pins have internal pull-up resistors.

VCC
Supply voltage.

P0.0 to P0.7
These are the eight I/O pins of port 0 of the standard 8051. These pins have no pull-up resistors. P0.0 to P0.7 are also used to provide the low addresses (A0 to A7) and the data during fetches from external program memory and during accesses to external data memory.

P2.0 to P2.7
These are the eight I/O pins of port 2 of the standard 8051. These pins have pull-up resistors. P2.0 to P2.7 are also used to provide the high address (A8 to A15) byte during fetches from external program memory and during accesses to external data memory.

EA/VPP
This is the external access enable pin on the standard 8051. EA should be connected to VCC for internal program executions. This pin also receives the programming voltage during programming.