Chapter

1

INTRODUCTION

1.1 A REVOLUTION IN INFORMATION PROCESSING[1]

The embedded information processing revolution is happening all around us. Electronics intelligence is hidden inside the products we use in our daily lives. As the cost of the integrated circuits that provide this intelligence has dropped over the years, the number of manufacturers using these devices—and their diverse applications—has exploded.

Competitive pressures require manufacturers to expand product functionality and provide differentiation while maintaining or reducing cost. To address these requirements, manufacturers use integrated circuit-based embedded control systems that provide an integrated solution for application-specific control requirements. Embedded control systems enable manufacturers to differentiate their product, replace less efficient electromechanical control devices, add product functionality, and significantly reduce product costs. In addition, embedded control systems facilitate the emergence of complete new classes of products. Embedded control systems typically incorporate microcontrollers for the principle activity, and sometimes are the sole component.

A microcontroller is a self-contained computer-on-a-chip consisting of a central processing unit, nonvolatile program memory, random access memory for data storage, and various input-output capabilities. In addition to the microcontroller, a complete embedded control system incorporates application-specific software and may include specialized peripheral device controllers and external, nonvolatile memory components, such as EEPROMs to store additional program software.

[1]This section was written by Steve Sanghi, CEO and President of Microchip Technology Inc., Chandler, Arizona.

Embedded control solutions have been incorporated into thousands of products and subassemblies in a wide variety of markets worldwide. Some of these applications include

- Automotive air bag systems
- Remote control devices
- Handheld tools
- Appliances
- Portable computers
- Cordless and cellular telephones
- Motor controls
- Security systems

The increasing demand for embedded control has made the market for microcontrollers one of the largest segments of the semiconductor market. Microcontrollers are currently available in 4-bit through 32-bit architectures. Although 4-bit microcontrollers are relatively inexpensive, typically costing under $1.00 each, they generally lack the minimum performance and features required by today's design engineers for product differentiation and are typically used only to produce basic functionality in products. Although 16-bit and 32-bit architectures provide very high performance, they can be expensive for most high-volume embedded control applications, typically costing $6.00 to $12.00 each. As a result, manufacturers of competitive, high-volume products have increasingly found 8-bit microcontrollers, which typically cost $1.00 to $8.00 each, to be the most cost-effective embedded control solution.

For example, a typical new automobile may include one 32-bit microcontroller for engine control; three 16-bit microcontrollers for transmission control, audio systems, and antilock braking; and up to fifty 8-bit microcontrollers to provide other embedded control functions, such as door locking, automatic windows, sun roof, adjustable seats, electric mirrors, air bags, fuel pump, speedometer, and the security and climate control systems.

The uses for 8-bit microcontrollers are multiplying, targeting many high-volume, low-cost applications and limited only by the imagination. Because 8-bit microcontrollers are so ubiquitous, successful engineers need to comprehend the many complexities of designing with these devices.

Microchip Technology Inc. designed the PIC18F452 to help embedded control engineers explore the many benefits of differentiating their end-product design by incorporating a very flexible, easy-to-use, flash-based microcontroller. The PIC18F452 is loaded with peripherals and comes with a comprehensive suite of development tools. This book will help readers learn the PIC18FXXX architecture rapidly and use the PIC18F452 device to differentiate products and enhance their end-market appeal.

1.2 THE LEARNING CURVE

A manufacturing principle that Microchip Technology handles adroitly is its use of learning curve economies. This principle states that each doubling of the quantity of parts produced results in a fixed percentage decrease in the unit cost of a part. Coupled with passing along the reduced costs to customers, these economies are used by a company to gain market share. In Microchip Technology's case, it shows up as what might otherwise seem to be an unusual pricing of parts. A new part such as the PIC18F452 microcontroller, for all of its new and attractive features, does not carry an elevated price relative to older PIC® microcontroller parts. Instead, it carries a price that reflects its manufacturing cost and follows a pricing regimen reflecting the reduction in that manufacturing cost as quantities increase. The result is illustrated in Figure 1-1, which shows Microchip's gain in market share in the world of 8-bit microcontrollers relative to other manufacturers. This is a world that has been dominated for years

1990 Rank	1993 Rank	1996 Rank	2000 Rank
Motorola	Motorola	Motorola	Motorola
Mitsubishi	Mitsubishi	Mitsubishi	Microchip
NEC	NEC	SGS-Thomson	NEC
Intel	Hitachi	NEC	Hitachi
Hitachi	Philips	Microchip	ST-Micro
Philips	Intel	Philips	Infineon
Matsushita	SGS	Zilog	Mitsubishi
National	Microchip	Hitachi	Philips
Siemens	Matsushita	Fujitsu	Toshiba
TI	Toshiba	Intel	Atmel
Sharp	National	Siemens	Zilog
Oki	Zilog	Toshiba	Fujitsu
Toshiba	TI	Matsushita	Matsushita
SGS-Thomson	Siemens	TI	Realtek
Zilog	Sharp	National	Samsung
Matra MHS	Oki	Temic	National
Sony	Sony	Sanyo	Sanyo
Fujitsu	Sanyo	Ricoh	Elan
AMD	Fujitsu	Oki	TI
Microchip	AMD	Sharp	Sony

Figure 1-1 Worldwide market share for producers of 8-bit microcontrollers, sorted by units shipped (Dataquest).

by Motorola. As shown in Figure 1-2, Microchip's market share has grown significantly relative to Motorola's, supporting Microchip's stated goal of becoming the number-one supplier of 8-bit microcontrollers in the world. And while the technical press regularly touts the features of new 16-bit and 32-bit microcontrollers, in fact the world of microcontrollers is dominated by 8-bit microcontrollers such as the PIC18F452 discussed in this book, as illustrated in Figure 1-3.

What this means for readers of this book is that their learning is focused on a family of parts that finds wide industrial use and is price competitive. Furthermore, the emphasis on Microchip's latest microcontroller architecture is well placed, given Microchip's propensity to gain market share with competitively priced new parts.

1.3 FLASH MEMORY TECHNOLOGY

The flash program memory in the PIC18F452 microcontroller permits the microcontroller to be programmed, erased, and programmed again repeatedly. In contrast to its windowed EPROM counterpart, the PIC18C452 microcontroller, it does not need a special programmer and an ultraviolet eraser to

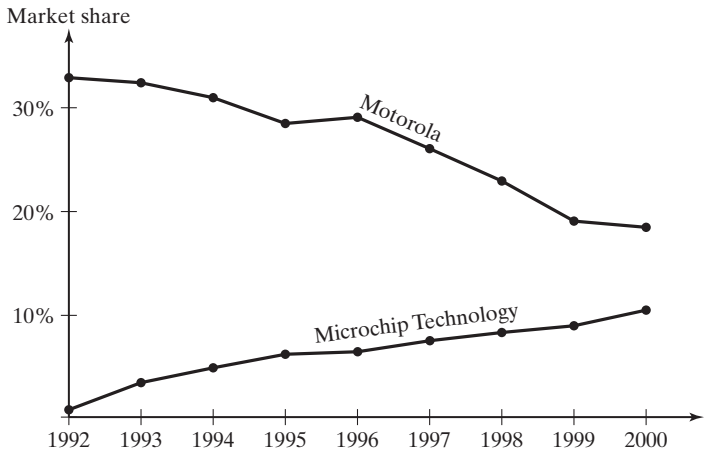

Figure 1-2 Market share of total number of 8-bit microcontrollers shipped per year (Dataquest).

achieve this reprogramming capability. The cost of its plastic package also contrasts favorably with the expensive ceramic package plus quartz window of the windowed PIC18C452 microcontroller. Some observers predict a major migration in microcontroller program memory technology to flash program memory. This migration is certainly happening for reprogrammable parts. For OTP (one-time programmable) parts made with an EPROM part in a windowless plastic package, such a migration would seem to depend on the equalization of the die sizes for the two technologies as well as on learning curve considerations.

The flash memory technology of the PIC18F452 microcontroller also has a profound effect on the cost of the development tools required in the implementation of an application. The "low-cost" approach

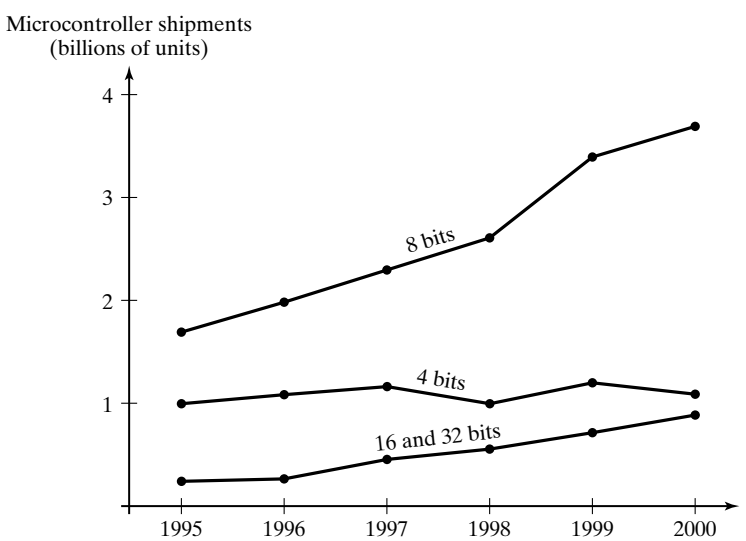

Figure 1-3 Microcontroller unit shipments per year, as distinguished by data word length (Dataquest).

to code development with a windowed EPROM part calls for a programmer and an ultraviolet eraser. It also inserts into the program-test-erase-reprogram-test code development cycle the need to shuffle among several parts to deal efficiently with an erase time of several minutes. In contrast, as will be seen in this book, a flash part can be reprogrammed in seconds in its target system environment with a low-cost "in-circuit debugger" that interacts with the microcontroller via three of its pins plus power and ground. Alternatively, it can be reprogrammed in seconds in its target system environment with the zero-cost *QwikBug* monitor program discussed in this book. This program, resident in the chip, uses the on-chip UART to establish communications with a PC.

1.4 MICROCONTROLLER FEATURE SET

The PIC18F452 microcontroller is actually one of a family of parts distinguished from each other on the basis of

- The number of pins available for inputs and outputs
- The amount of memory available for programs and for variables

The part distinctions are listed in Figure 1-4. The package alternatives are shown in Figure 1-5. Because of the package alternatives available to this family of parts, it is interesting to note that in spite of its 40 or 44 pins, the PIC18F452 microcontroller has both the largest and the smallest footprint, compared with the 28-pin parts.

A block diagram of the PIC18F452 (and the PIC18F442) is shown in Figure 1-6. The use of the various features of this chip forms the heart of this book. For now, it is enough to understand that this chip has a rich feature set, permitting it to meet a wide range of applications.

A block diagram of the 28-pin PIC18F252 (and the PIC18F242) is shown in Figure 1-7. It is identical to the block diagram of the PIC18F452 except for the absence of PORTD and PORTE and the resources attached to the pins of these two ports.

Features of this PIC18FXXX family of microcontroller parts that designers find attractive are

- *Speed:* With its maximum internal clock rate of 10 MHz and its 16-bit-wide instruction bus, the CPU can execute most of its instructions in 0.1 μs, or ten instructions per microsecond.
- *Flexible timer resources:* Four independent timers plus two capture/compare/pulse-width-modulation modules support timing measurements and output interval control with a timing resolution as fine as 0.1 μs.
- *Interrupt control:* Seventeen independent interrupt sources control when the CPU deals with each source.

Part Number	Program Memory (16-bit words)	RAM Bytes	Total Pins	I/O Pins	Package size—length × width, including pins				
					40-pin DIP	44-pin PLCC	44-pin TQFP	28-pin DIP	28-pin SOIC
PIC18F452	16384	1536	40/44	33	2.058″ × 0.600″	0.690″ × 0.690″	0.472″ × 0.472″		
PIC18F442	8192	768	40/44	33	2.058″ × 0.600″	0.690″ × 0.690″	0.472″ × 0.472″		
PIC18F252	16384	1536	28	22				1.345″ × 0.300″	0.704″ × 0.407″
PIC18F242	8192	768	28	22				1.345″ × 0.300″	0.704″ × 0.407″

Figure 1-4 Alternative family member parts.

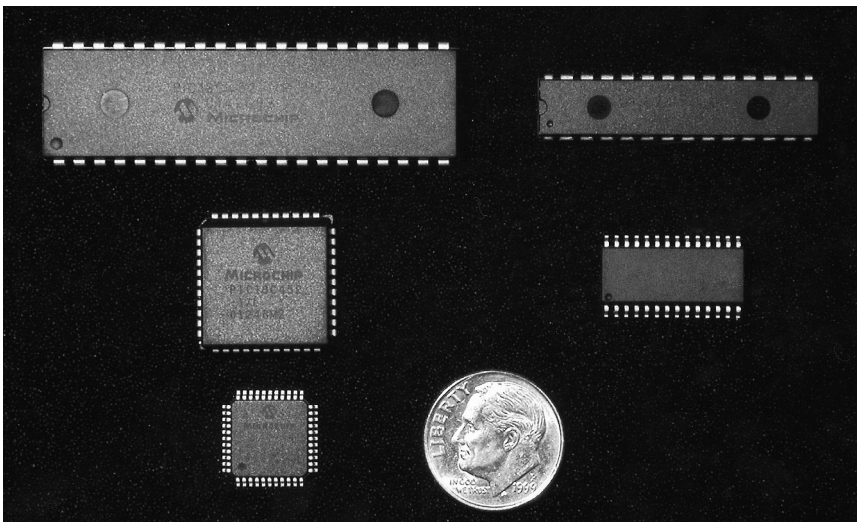

Figure 1-5 PIC18FXXX family parts.

- *Robustness:* I/O pins can drive loads of up to 25 mA as outputs and are protected against static electricity damage as inputs.
- *Error recovery:* The built-in watchdog timer, brown-out reset circuitry, and low-voltage detect circuitry provide alternative means for detecting an actual or impending malfunction and dealing with it.
- *Support of low-power operation:* In addition to being an exceedingly power-stingy part, the PIC18F452 microcontroller can greatly extend battery life by alternating intervals of low-power sleep mode with intervals of normal operation. The watchdog timer can be used to produce a low duty cycle and, thereby, a low average power dissipation (Section 20.7).
- *I/O expansion:* The built-in serial peripheral interface (Chapter 15) can make use of standard 16-pin shift-register parts to add any number of I/O pins. The built-in I^2C interface (Chapter 17) supports the addition of specialty peripheral parts.
- *Math support:* Microchip supports the PIC18F452 microcontroller with a variety of multiplication and division subroutines for multiple-byte, fixed-point numbers and for floating-point numbers (Chapter 14).
- *Mail-order support:* Digi-Key Corporation (www.digikey.com) and Newark Electronics (www.newark.com) provide both on-line and telephone purchasing of PIC18FXXX microcontroller parts as well as development tools.
- *Free software tools:* To encourage new users and to support upgrades to veteran users, Microchip makes its MPLAB® Integrated Development Package (consisting of assembler, simulator, and user interface) as well as all manuals and application notes available at no cost from their Web site (www.microchip.com).
- *Development tool versatility:* The PIC18F452 microcontroller's flash program memory supports not only a standard emulator that includes the ability to capture trace information, it also supports a low-cost in-circuit debugger and a zero-cost *QwikBug* monitor program. Each of these permits the loading and execution of a user program as well as the use of breakpoints, memory/register modification, and single stepping (Section 4.4).

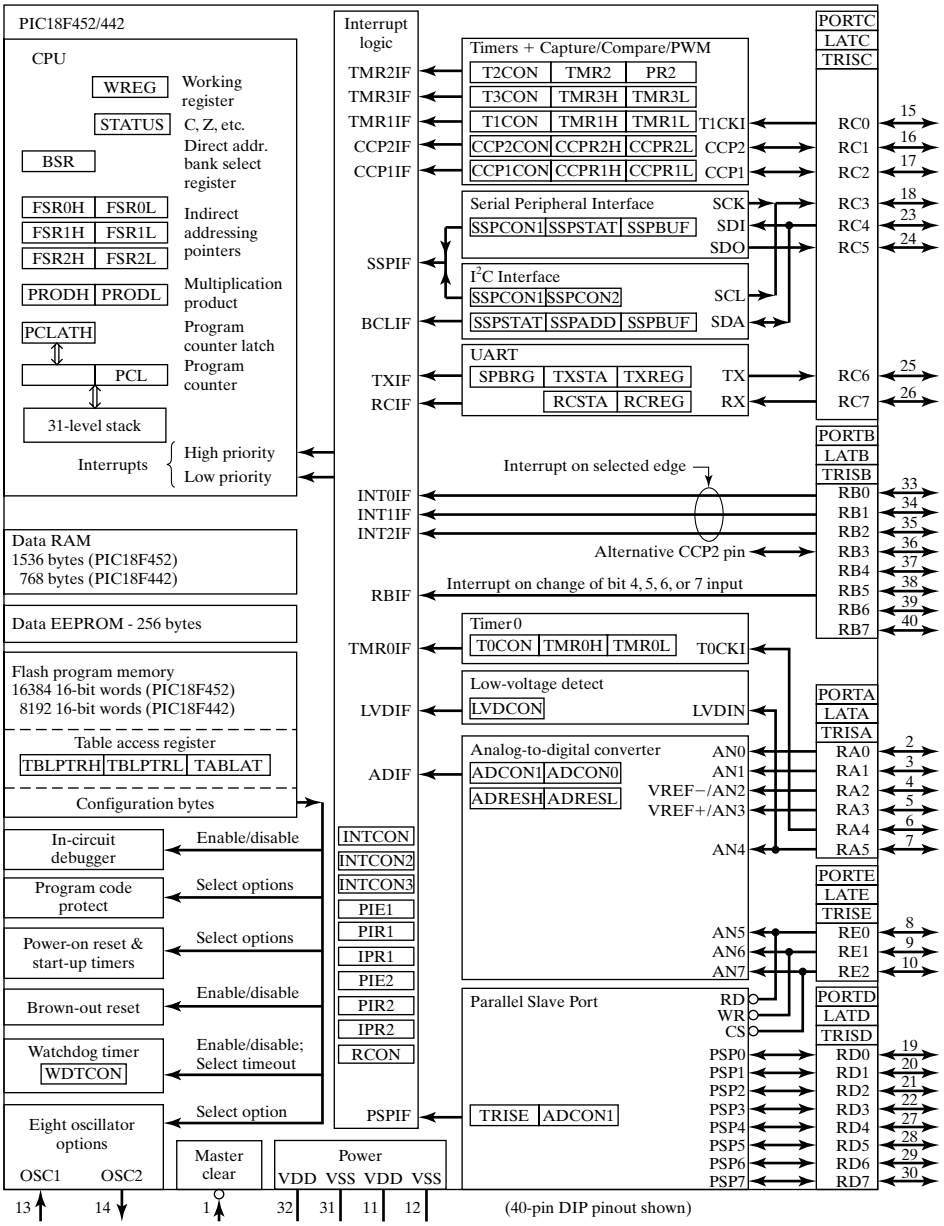

Figure 1-6 PIC18F452/442 block diagram.

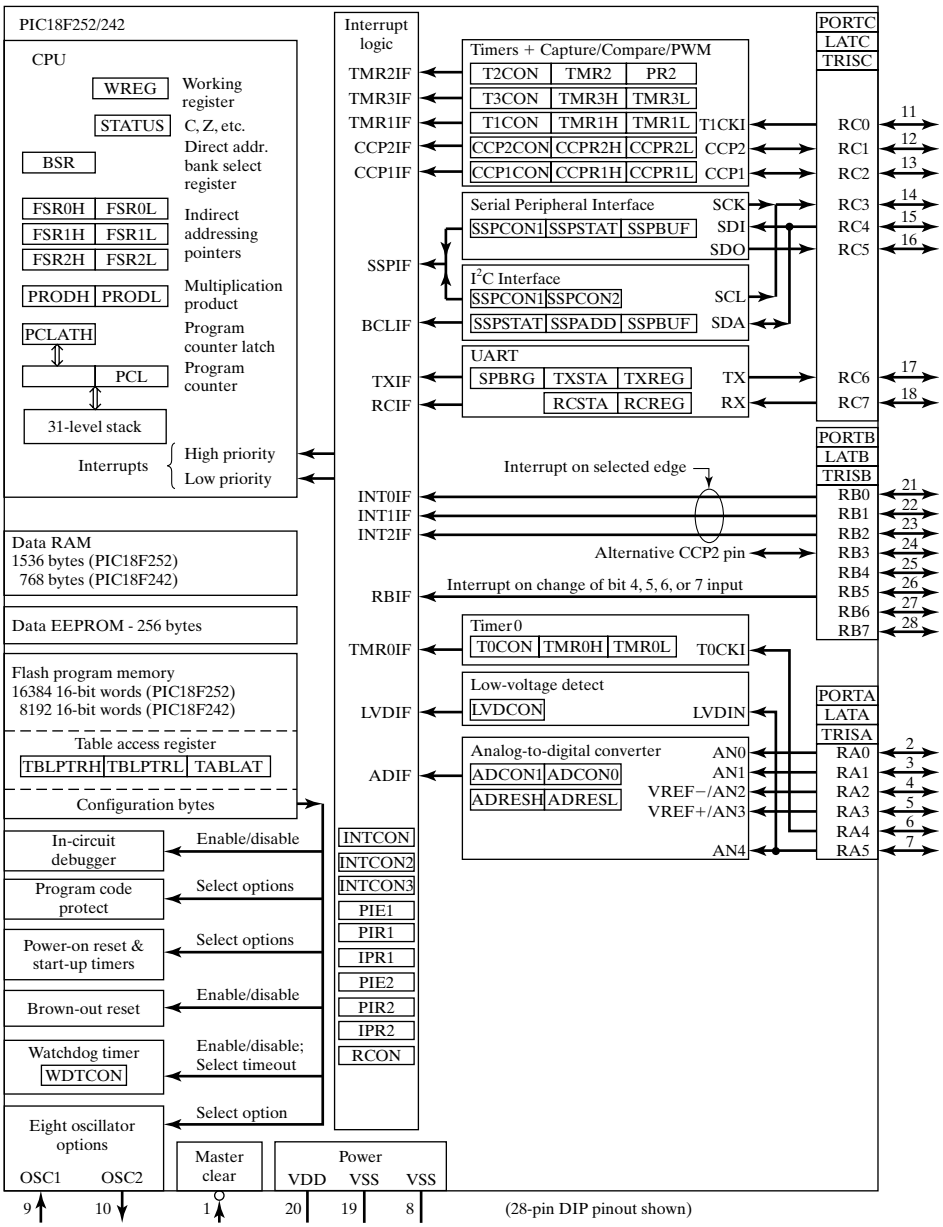

Figure 1-7 PIC18F252/242 block diagram.