Harman Microcontrollers 2 CENG 5434

Microprocessors and microcontrollers are designed for various applications. We will be interested in *embedded systems*.

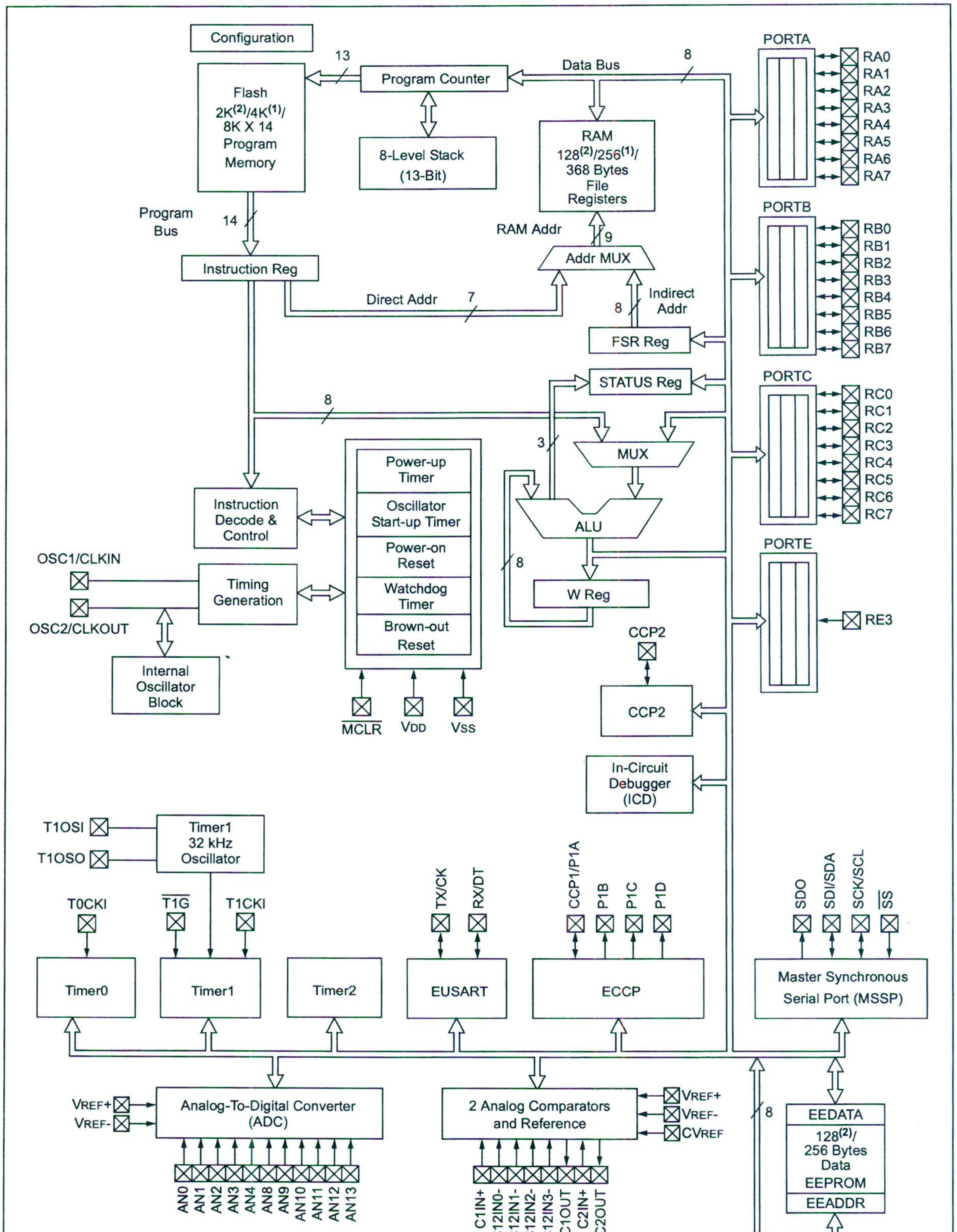
Embedded system A microcontroller- or microprocessor-based computer system dedicated to a specific application.

This is contrasted with general-purpose computer systems such as desktop workstations. When choosing a microcontroller for a project some important items to consider are listed in the table.

Type	*Support*
The microcontroller	8-,16-, or 32-bit devices and families
Modules	RAM, ROM, Timers, IO, etc
Expansion	Various compatible chips in family
Software	Available Compilers C,C++
	Code Warrior, Composer, etc.
Development	In Circuit Debuggers and Emulators
	Systems for motor control, etc.
Documentation	Manuals, application notes and training
Hardware	Various computer boards to aid development
The Company	Reliable? Second-source? Tech Help?
Financial	Cost of parts and system, training, etc.

Table 1: Table of Support for Families of Microcontrollers

FIGURE 1-1: PIC16F882/883/886 BLOCK DIAGRAM



Note 1: PIC16F883 only.
2: PIC16F882 only.

2

3 PIC and Cortex-M3 Compared

Direct comparisons are necessarily difficult between these two architectures. Both are available in any number of different configurations. While the Cortex-M3 is arguably more standardized than the PIC implementations, there are still several implementation options available to individual silicon fabricators (e.g. number of interrupts and depth of priority scheme, memory protection, debug configuration etc.).

For the purposes of meaningful comparison, we have selected the PIC18 architecture and will be looking at devices like the PIC18F44J11.

On the Cortex-M3 side, we have selected the STM32F101T4 from STMicroelectronics.

	PIC18F44J11	**STM32F101T4**
Program memory (flash)	16 Kbytes	16 Kbytes
Data memory (RAM)	3.8 Kbytes	4 Kbytes
Max clock frequency	48 MHz	36 MHz
GPIO pins	34	26
ADC	13-channel x 10-bit	10-channel x 12-bit
Timers	2 x 8-bit, 3 x 16-bit	2 x 16-bit + SysTick
Watchdog timer	Y	Y (Two)
SPI	1	1
I2C	1	1
USART	2	2
PWM	2	N/A
Comparators	2	N/A
RTC	Y	Y
External interrupt sources	4 (+30 internal)	43 (+ 16 internal)
Interrupt prioritization	2 levels	16 levels
Vectored Interrupt Controller	N	Y
Power-saving modes	Idle/Sleep/DeepSleep	Sleep/Stop/Standby
DMA		7-channel
Debug port	ICD (In-Circuit Debug)	SWJ-DP JTAG port
Voltage Detection	Y	Y

Price/100 2.88 DigiKey

MICROCHIP

PIC24FV32KA304 FAMILY

20/28/44/48-Pin, General Purpose, 16-Bit Flash Microcontrollers with XLP Technology

Power Management Modes:

- Run – CPU, Flash, SRAM and Peripherals On
- Doze – CPU Clock Runs Slower than Peripherals
- Idle – CPU Off, Flash, SRAM and Peripherals On
- Sleep – CPU, Flash and Peripherals Off and SRAM on
- Deep Sleep – CPU, Flash, SRAM and Most Peripherals Off; Multiple Autonomous Wake-up Sources
- Low-Power Consumption:
  - Run mode currents down to 8 μA, typical
  - Idle mode currents down to 2.2 μA, typical
  - Deep Sleep mode currents down to 20 nA, typical
  - Real-Time Clock/Calendar currents down to 700 nA, 32 kHz, 1.8V
  - Watchdog Timer 500 nA, 1.8V typical

High-Performance CPU:

- Modified Harvard Architecture
- Up to 16 MIPS Operation @ 32 MHz
- 8 MHz Internal Oscillator with 4x PLL Option and Multiple Divide Options
- 17-Bit by 17-Bit Single-Cycle Hardware Multiplier
- 32-Bit by 16-Bit Hardware Divider 16-Bit x 16-Bit Working Register Array
- C Compiler Optimized Instruction Set Architecture

Peripheral Features:

- Hardware Real-Time Clock and Calendar (RTCC):
  - Provides clock, calendar and alarm functions
  - Can run in Deep Sleep mode
  - Can use 50/60 Hz power line input as clock source
- Programmable 32-bit Cyclic Redundancy Check (CRC)
- Multiple Serial Communication modules:
  - Two 3-/4-wire SPI modules
  - Two I^{2}C™ modules with multi-master/slave support
  - Two UART modules supporting RS-485, RS-232, LIN/J2602, IrDA®
- Five 16-Bit Timers/Counters with Programmable Prescaler:
  - Can be paired as 32-bit timers/counters
- Three 16-Bit Capture Inputs with Dedicated Timers
- Three 16-Bit Compare/PWM Output with Dedicated Timers (DIGITAL)
- Configurable Open-Drain Outputs on Digital I/O Pins
- Up to Three External Interrupt Sources

Analog Features:

- 12-Bit, up to 16-Channel Analog-to-Digital Converter:
  - 100 ksps conversion rate
  - Conversion available during Sleep and Idle
  - Auto-sampling timer-based option for Sleep and Idle modes
  - Wake on auto-compare option
- Dual Rail-to-Rail Analog Comparators with Programmable Input/Output Configuration
- On-Chip Voltage Reference
- Internal Temperature Sensor
- Charge Time Measurement Unit (CTMU):
  - Used for capacitance sensing, 16 channels
  - Time measurement, down to 200 ps resolution
  - Delay/pulse generation, down to 1 ns resolution

Special Microcontroller Features:

- Wide Operating Voltage Range:
  - 1.8V to 3.6V (PIC24F devices)
  - 2.0V to 5.5V (PIC24FV devices)
- Low Power Wake-up Sources and Supervisors:
  - Ultra-Low Power Wake-up (ULPWU) for Sleep/Deep Sleep
  - Low-Power Watchdog Timer (DSWDT) for Deep Sleep
  - Extreme Low-Power Brown-out Reset (DSBOR) for Deep Sleep, LPBOR for all other modes
- System Frequency Range Declaration bits:
  - Declaring the frequency range optimizes the current consumption.
- Standard Watchdog Timer (WDT) with On-Chip, Low-Power RC Oscillator for Reliable Operation
- Programmable High/Low-Voltage Detect (HLVD)
- Standard Brown-out Reset (BOR) with 3 Programmable Trip Points that can be Disabled in Sleep
- High-Current Sink/Source (18 mA/18 mA) on All I/O Pins
- Flash Program Memory:
  - Erase/write cycles: 10,000 minimum
  - 40 years' data retention minimum
- Data EEPROM:
  - Erase/write cycles: 100,000 minimum
  - 40 years' data retention minimum
- Fail-Safe Clock Monitor
- Programmable Reference Clock Output
- Self-Programmable under Software Control
- In-Circuit Serial Programming™ (ICSP™) and In-Circuit Debug (ICD) via 2 Pins

PIC24F Device	Pins	Memory			Timers 16-Bit	Capture Input	Compare/PWM Output	UART w/ IrDA®	SPI	I^2C™	12-Bit A/D (ch)	Comparators	CTMU (ch)	RTCC
		Flash Program (bytes)	SRAM (bytes)	EE Data (bytes)										
PIC24FV16KA301 /PIC24F16KA301	20	16K	2K	512	5	3	3	2	2	2	12	3	12	Y
PIC24FV32KA301 /PIC24F32KA301	20	32K	2K	512	5	3	3	2	2	2	12	3	12	Y
PIC24FV16KA302 /PIC24F16KA302	28	16K	2K	512	5	3	3	2	2	2	13	3	13	Y
PIC24FV32KA302 /PIC24F32KA302	28	32K	2K	512	5	3	3	2	2	2	13	3	13	Y
PIC24FV16KA304 /PIC24F16KA304	44	16K	2K	512	5	3	3	2	2	2	16	3	16	Y
PIC24FV32KA304 /PIC24F32KA304	44	32K	2K	512	5	3	3	2	2	2	16	3	16	Y

FV 2 to 5.5V
F 1.8 to 3.6V

12 bit

Charge time measurement unit

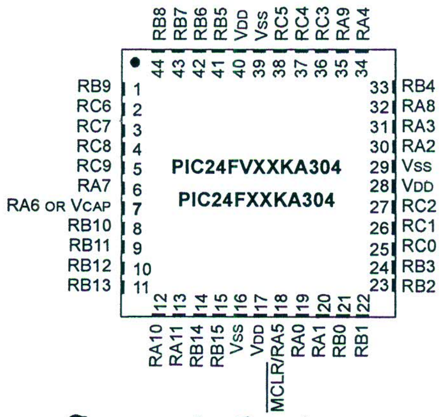
Real time clock + calendar

Pin Diagrams

Thin Quad Flatpack

44-Pin TQFP/QFN[1,2,3]

Quad Flat No lead



FV 2 to 5.5V
F 1.8 to 3.6V

Pin	Pin Features	
	PIC24FVXXKA304	PIC24FXXKA304
1	SDA1/T1CK/U1RTS/CTED4/CN21/RB9	SDA1/T1CK/U1RTS/CTED4/CN21/RB9
2	U1RX/CN18/RC6	U1RX/CN18/RC6
3	U1TX/CN17/RC7	U1TX/CN17/RC7
4	OC2/CN20/RC8	OC2/CN20/RC8
5	IC2/CTED7/CN19/RC9	IC2/CTED7/CN19/RC9
6	IC1/CTED3/CN9/RA7	IC1/CTED3/CN9/RA7
7	**VCAP**	**C2OUT/OC1/CTED1/INT2/CN8/RA6**
8	PGED2/SDI1/CTED11/CN16/RB10	PGED2/SDI1/CTED11/CN16/RB10
9	PGEC2/SCK1/CTED9/CN15/RB11	PGEC2/SCK1/CTED9/CN15/RB11
10	**AN12/LVDIN/CTED2/INT2/CN14/RB12**	**AN12/LVDIN/CTED2/CN14/RB12**
11	AN11/SDO1/CTPLS/CN13/RB13	AN11/SDO1/CTPLS/CN13/RB13
12	OC3/CN35/RA10	OC3/CN35/RA10
13	IC3/CTED8/CN36/RA11	IC3/CTED8/CN36/RA11
14	CVREF/AN10/C3INB/RTCC/C1OUT/OCFA/CTED5/INT1/CN12/RB14	CVREF/AN10/C3INB/RTCC/C1OUT/OCFA/CTED5/INT1/CN12/RB14
15	AN9/C3INA/T3CK/T2CK/REFO/SS1/CTED6/CN11/RB15	AN9/C3INA/T3CK/T2CK/REFO/SS1/CTED6/CN11/RB15
16	VSS/AVSS	VSS/AVSS
17	VDD/AVDD	VDD/AVDD
18	MCLR/VPP/RA5	MCLR/VPP/RA5
19	VREF+/CVREF+/AN0/C3INC/CTED1/CN2/RA0	VREF+/CVREF+/AN0/C3INC/CN2/RA0
20	CVREF-/VREF-/AN1/CN3/RA1	CVREF-/VREF-/AN1/CN3/RA1
21	PGED1/AN2/ULPWU/CTCMP/C1IND/C2INB/C3IND/U2TX/CN4/RB0	PGED1/AN2/ULPWU/CTCMP/C1IND/C2INB/C3IND/U2TX/CN4/RB0
22	PGEC1/AN3/C1INC/C2INA/U2RX/CTED12/CN5/RB1	PGEC1/AN3/C1INC/C2INA/U2RX/CTED12/CN5/RB1
23	AN4/C1INB/C2IND/SDA2/T5CK/T4CK/CTED13/CN6/RB2	AN4/C1INB/C2IND/SDA2/T5CK/T4CK/CTED13/CN6/RB2
24	AN5/C1INA/C2INC/SCL2/CN7/RB3	AN5/C1INA/C2INC/SCL2/CN7/RB3
25	AN6/CN32/RC0	AN6/CN32/RC0
26	AN7/CN31/RC1	AN7/CN31/RC1
27	AN8/CN10/RC2	AN8/CN10/RC2
28	VDD	VDD
29	VSS	VSS
30	OSCI/AN13/CLKI/CN30/RA2	OSCI/AN13/CLKI/CN30/RA2
31	OSCO/AN14/CLKO/CN29/RA3	OSCO/AN14/CLKO/CN29/RA3
32	OCFB/CN33/RA8	OCFB/CN33/RA8
33	SOSCI/AN15/U2RTS/CN1/RB4	SOSCI/AN15/U2RTS/CN1/RB4
34	SOSCO/SCLKI/U2CTS/CN0/RA4	SOSCO/SCLKI/U2CTS/CN0/RA4
35	SS2/CN34/RA9	SS2/CN34/RA9
36	SDI2/CN28/RC3	SDI2/CN28/RC3
37	SDO2/CN25/RC4	SDO2/CN25/RC4
38	SCK2/CN26/RC5	SCK2/CN26/RC5
39	VSS	VSS
40	VDD	VDD
41	PGED3/ASDA1[2]/CN27/RB5	PGED3/ASDA1[2]/CN27/RB5
42	PGEC3/ASCL1[2]/CN24/RB6	PGEC3/ASCL1[2]/CN24/RB6
43	INT0/CN23/RB7	INT0/CN23/RB7
44	SCL1/U1CTS/C3OUT/CTED10/CN22/RB8	SCL1/U1CTS/C3OUT/CTED10/CN22/RB8

Legend: Pin numbers in **bold** indicate pin function differences between PIC24FV and PIC24F devices.

Note 1: Exposed pad on underside of device is connected to VSS.

2: Alternative multiplexing for SDA1 (ASDA1) and SCL1 (ASCL1) when the I2CSEL Configuration bit is set.

3: PIC24F32KA304 device pins have a maximum voltage of 3.6V and are not 5V tolerant.

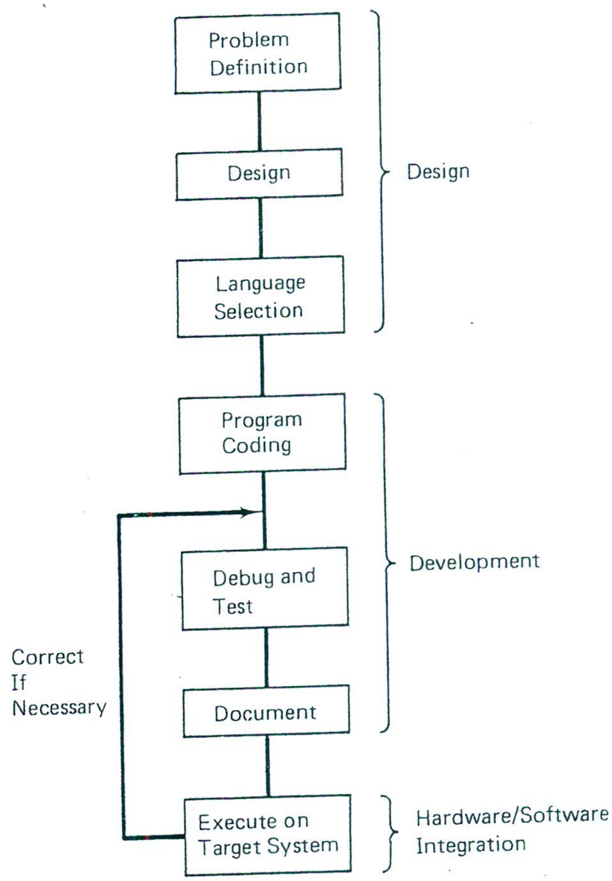
The PIC microcontrollers have a great deal of support from Microchip and third-party vendors. This includes software development systems, real-time operating systems, simulators and emulators.

Development	*Support*
High Tech C	C for PIC chips
Features	Assembly and interrupt handling
RTOS	Real-time OS
Development	In Circuit Debuggers MPLAB ICD 3 (219), *RealICE*(500)
Documentation	Many books, Manuals, and application notes
Hardware	Evaluation boards
The Company	Reliable. Tech Help.
General	Extensive third party support
	Microchip Technology User Forums
Financial	Fairly inexpensive chips and development systems.

The choice of development tools depends on the size and scope of the project. Today, almost of the software development is done on PCs so the compilers and assemblers are *cross-software* unless they are targeting the Intel processors.

1. The C and assembly software generate code for the target processor.
2. The real time operating systems for microcontrollers are very basic compared to those for high-performance processors.
3. The evaluation boards hold the processor and interfacing chips and often have room for user-supplied logic.
4. Emulators are necessary when the microcontroller is used in a real target board.
5. Many microcontrollers have the Background Debug Mode (or JTAG) so the software can be tested when the chip is in the target board and even soldered into the board.

Figure 1.3 Software development and hardware/software integration.



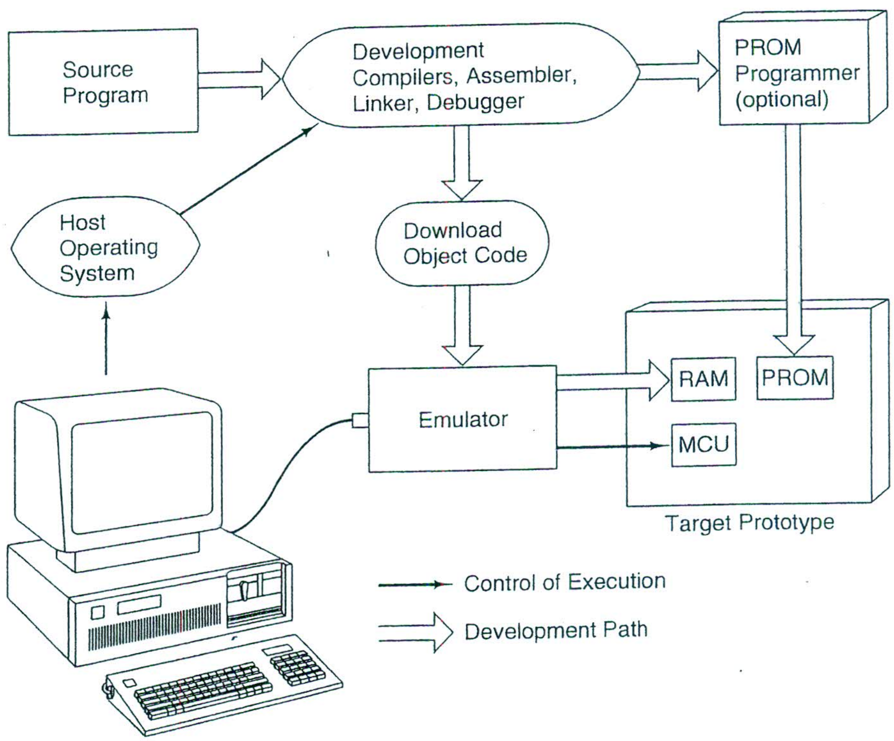


Figure 1.4 Development system for hardware/software integration.

Example development systems MPLAB IDE and ICD. See Predko pages 629-639.

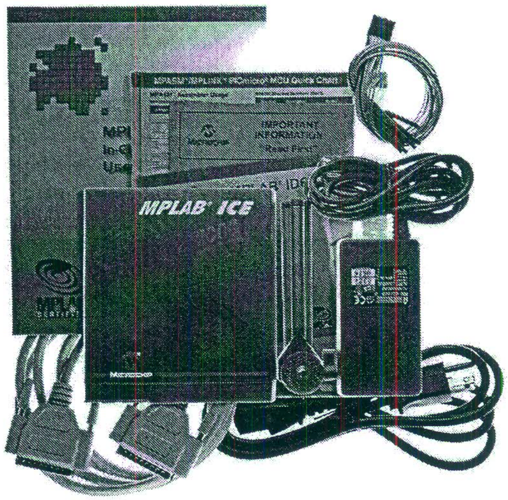


Figure 1: PIC Development ICE2000

For many PIC products, the microprocessor in the target product is replaced by the In Circuit Emulator header. The cost is about $1000.00.

An alternative is to use the on-board debugging code of the microcontroller. This requries a simple connection and a development system such as the ICD3 (In Circuit Debugger) for about $200.00.

We shall see later that the serial connection to the emulator uses three pins of PortB of the 16F877.

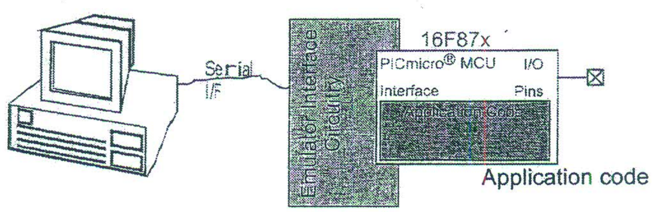


Figure 14-4 16F87x built-in emulator

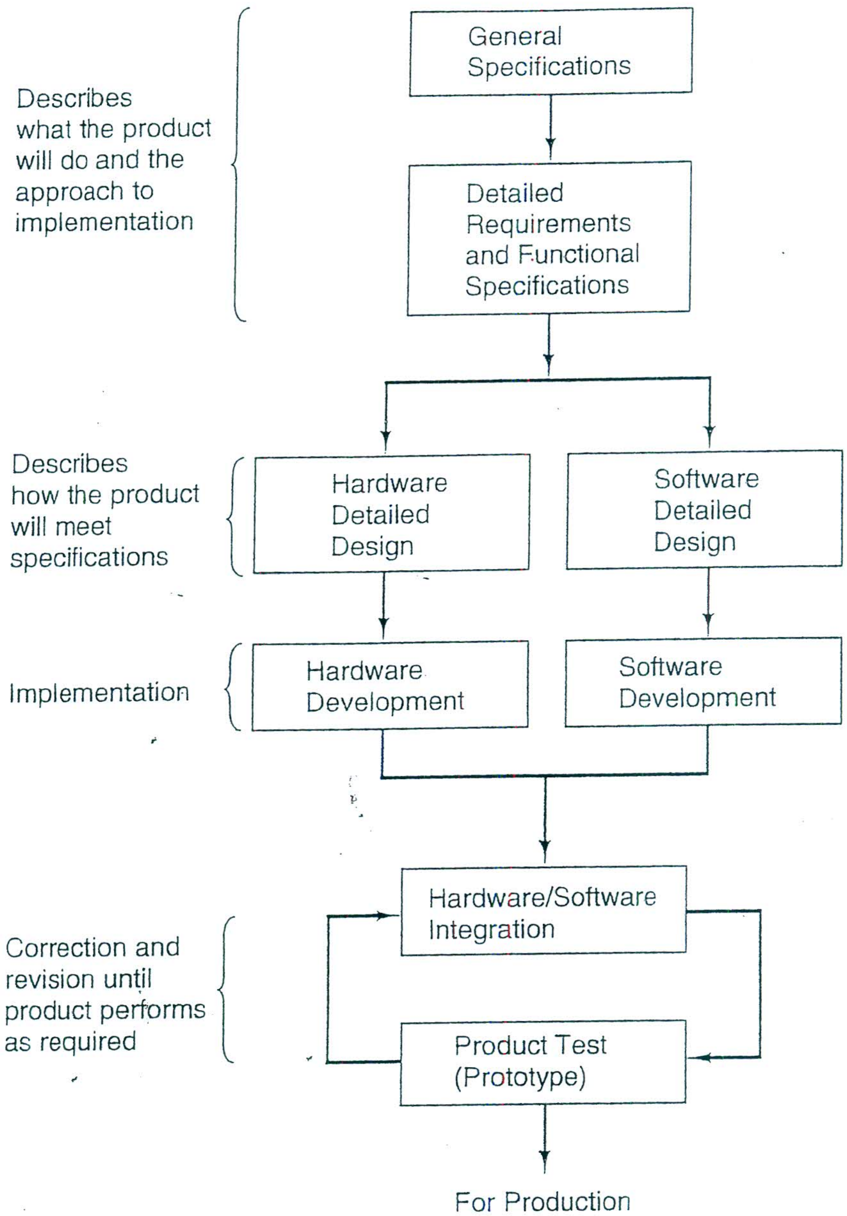


Figure 1.7 Product design, development and testing cycle.

We shall see later that the development of a product or a system requires many "tools" to successfully complete all the steps shown in the design, development, and testing cycle.

General Tools	*Support*
Configuration Management	Control Documentation
Simulation	Check the overall design
Timing analysis	Test system timing requirements
In Circuit Emulators	Integrate SW and HW
Integrated Development Environments	Integrate SW and HW

Software Tool	*Support*
Assembler/Compiler	Language for programming
Debugger	Correct software errors
Development	In Circuit Debuggers MPLAB ICD 3 (219), *RealICE*(500)
Special	Libraries, testing SW
Modeling	UML, graphic design and GUI tools, etc.

Hardware Tool	*Support*
Oscilloscope	View analog signals
Logic analyzer	View digital signals
Special	Frequency analyzers, etc.