Embedded Systems Design
(630470)

Lecture 3

Microcontroller Architecture
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INTERNAL ARCHITECTURE

- All MCs use one of two basic design models: 
  *Harvard* Architecture and *von-Neumann* architecture.
- They represent two different ways of exchanging data between CPU and memory.
- **VON-NEUMANN ARCHITECTURE:**

- **HARVARD ARCHITECTURE:**
CISC and RISC

- MCs with Harvard architecture are called "RISC MCs". MCs with von-Neumann's architecture are called 'CISC microcontrollers'.
- The PIC16F84 MC has a RISC architecture.
- Harvard architecture is a newer concept than von-Neumann's.
- In Harvard architecture, data bus and address bus are separate. Thus a greater flow of data is possible through the CPU, and of course, a greater speed of work.
- PIC16F84 uses 14 bits for instructions which allows for all instructions to be one word instructions.
- It is also typical for Harvard architecture to have fewer instructions than von-Neumann's, and to have instructions usually executed in one cycle.
- The PIC16F84 MC has 35 instructions. All of these instructions are executed in one cycle except for jump and branch instructions.
Popular PIC MCU Families

**PIC10:** Extremely small footprint, 6-pins

**PIC12:** Low-cost, easy-to-use, 8-pins

**PIC16:** NEW Enhanced Mid-Range core optimized for C with simplified memory map

**PIC18:** High 8-bit performance optimized for C with advanced communication peripherals, low-power, up to 128 KB Flash and 80-pins

**PIC24:** 16-bit families for more memory and faster peripherals including low power and high performance

**dsPIC® DSCs:** Digital signal control with motor control and power conversion peripherals, seamless migration with PIC24 MCUs

**PIC32:** Up to 80 MHz of 32-bit performance, compatible with 8- & 16-bit devices
- Broad portfolio of more than 550 PIC microcontrollers
  - From .5K to 512 KB Flash
  - From 0.5 to 80 MIPS performance
  - Multiple package options from 6- to 100-pins
  - nanoWatt XLP™ for eXtreme Low Power, <20 nA Sleep mode

- Comprehensive technical documentation and free software
  - Easy to get your designs done fast
  - Free software for USB, TCP-IP, ZigBee®, touch sensing, display and more
  - Leverage thousands of app notes, code examples and software libraries

- MPLAB® IDE is absolutely free and the MPLAB tool suite supports ALL of Microchip’s 8-, 16- and 32-bit microcontrollers
  - Easy code migration
  - Free C Compiler without code size limitations
  - User-friendly, inexpensive programming and debug tools
  - Low-cost demo boards help speed up prototyping efforts

- Easy-to-Use, Faster Time-to-Market
  - C-code friendly with industry-leading code efficiency
  - PIC Architecture is easy to learn, easy to use

- Easy migration with pin and code compatibility
  - One MCU platform for all of your applications
- Wide product availability and shortest lead times in the industry
  - Worldwide fulfillment channels
  - Long product life cycles – we are still manufacturing the original PIC MCUs

- The only supplier to bring USB, LCD, Ethernet, Touch Sensing and CAN to the 8-bit market
  - Industry-leading integrated peripherals
  - Integrated nanoWatt XLP technology
  - Communication peripherals (SPI, I²C™, UART, USB, wireless)
  - Analog (8-, 10- and 12-bit ADC, comparators)

- World-class, 24/7 technical support and training
  - World-wide field application engineers
  - Built to support over 60,000 customers
  - Comprehensive web seminars, videos, hands-on training, “Lunch & Learns” and customer conferences
  - Leverage on-line community support from other developers on the Microchip Forums
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<tbody>
<tr>
<td><strong>Base-Line 8-bit architecture, 12-bit Instruction Word Length</strong></td>
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<tr>
<td>PIC10FXXX</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>1 x 8</td>
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<tr>
<td>PIC12FXXX</td>
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<td>25 - 38</td>
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<td>4 - 8</td>
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<td>EEPROM</td>
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<tr>
<td>PIC16FXXX</td>
<td>0.75 - 3</td>
<td>25 - 134</td>
<td>14 - 44</td>
<td>20</td>
<td>0 - 3</td>
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<td>0 - 2</td>
<td>1 x 8</td>
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<td>EEPROM</td>
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<tr>
<td>PIC16HVXXXX</td>
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<td>25</td>
<td>18 - 20</td>
<td>20</td>
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<td>1 x 8</td>
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<td>Vdd = 15V</td>
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<td><strong>Mid-Range 8-bit architecture, 14-bit Instruction Word Length</strong></td>
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<tr>
<td>PIC12FXXX</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 - 2 x 8</td>
<td>-</td>
<td>0 - 1</td>
<td>EEPROM</td>
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<tr>
<td>PIC12HVXXXX</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 - 2 x 8</td>
<td>-</td>
<td>0 - 1</td>
<td>-</td>
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<tr>
<td>PIC16FXXX</td>
<td>1.75 - 14</td>
<td>64 - 368</td>
<td>14 - 64</td>
<td>20</td>
<td>0 - 13</td>
<td>8 or 10</td>
<td>0 - 2</td>
<td>2 x 8</td>
<td>USART/I2C/SPI</td>
<td>0 - 3</td>
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PIC16F84A

18-pin Enhanced FLASH/EEPROM 8-Bit Microcontroller

High Performance RISC CPU Features:
• Only 35 single word instructions to learn
• All instructions single-cycle except for program branches which are two-cycle
• Operating speed: DC - 20 MHz clock input
• 1024 words of program memory
• 68 bytes of Data RAM
• 64 bytes of Data EEPROM
• 14-bit wide instruction words
• 8-bit wide data bytes
• 15 Special Function Hardware registers

Peripheral Features:
• 13 I/O pins with individual direction control
• High current sink/source for direct LED drive
  - 25 mA sink max. per pin
  - 25 mA source max. per pin
• TMR0: 8-bit timer-counter with 8-bit programmable prescaler
Special Microcontroller Features:

- 10,000 erase/write cycles Enhanced FLASH Program memory typical
- 10,000,000 typical erase/write cycles EEPROM Data memory typical
- EEPROM Data Retention > 40 years
- In-Circuit Serial Programming™ (ICSP™) - via two pins
- Power-on Reset (POR), Power-up Timer (PWRT), Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own On-Chip RC Oscillator for reliable operation
- Code protection
- Power saving SLEEP mode

CMOS Enhanced FLASH/EEPROM Technology:

- Low power, high speed technology
- Fully static design
- Wide operating voltage range:
  - Commercial: 2.0V to 5.5V
  - Industrial: 2.0V to 5.5V
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 15 μA typical @ 2V, 32 kHz
  - < 0.5 μA typical standby current @ 2V
THE PIC16F887 BASIC FEATURES:

RISC architecture
Only 35 instructions to learn
All single-cycle instructions except branches

Operating frequency 0-20 MHz
Precision internal oscillator
Factory calibrated
Software selectable frequency range of 8MHz to 31KHz

Power supply voltage 2.0-5.5V
Consumption: 220uA (2.0V, 4MHz), 11uA (2.0 V, 32 KHz)
50nA (stand-by mode)

Power-Saving Sleep Mode

35 input/output pins
High current source/sink for direct LED drive
software and individually programmable pull-up resistor
Interrupt-on-Change pin

8K ROM memory in FLASH technology
Chip can be reprogrammed up to 100,000 times

In-Circuit Serial Programming Option
Chip can be programmed even embedded in the target device
THE PIC16F887 BASIC FEATURES:

256 bytes EEPROM memory
Data can be written more than 1,000,000 times
368 bytes RAM memory
A/D converter:
14-channels
10-bit resolution
3 independent timers/counters
Watch-dog timer
Analogue comparator module with
Two analogue comparators
Fixed voltage reference (0.6V)
Programmable on-chip voltage reference
PWM output steering control
Enhanced USART module
Supports RS-485, RS-232 and LIN2.0
Auto-Baud Detect
Master Synchronous Serial Port (MSSP)
Pipelining:

Clock/Instruction Cycle
1. MOVW 55h
2. MOVWF PORTB
3. CALL SUB_1
4. BSF PORTA, BIT3 (Forced NOP)
5. Instruction @address SUB_1

All instructions are single cycle except for any program branches. These take two cycles since the fetch instructions is "flushed" from the pipeline while the new instruction is being fetched and then executed.

Instruction Pipeline Flow
Pin no.1: **RA2** Second pin on port A.
Pin no.2: **RA3** Third pin on port A.
Pin no.3: **RA4** Fourth pin on port A. TOCK1 which functions as a timer is also found on this pin.
Pin no.4: **MCLR** Reset i/p and Vpp programming voltage.
Pin no.5: **Vss** Ground of power supply.
Pin no.6: **RB0** Zero pin on port B. Interrupt input.
Pin no.7: **RB1** First pin on port B.
Pin no.8: **RB2** Second pin on port B.
Pin no.9: **RB3** Third pin on port B.
Pin no.10: **RB4** Fourth pin on port B.
Pin no.11: **RB5** Fifth pin on port B.
Pin no.12: **RB6** Sixth pin on port B. 'Clock' line in program mode.
Pin no.13: **RB7** Seventh pin on port B. 'Data' line in program mode.
Pin no.14: **Vdd** Positive power supply pole.
Pin no.15: **OSC2** Pin for connecting with an oscillator.
Pin no.16: **OSC1** Pin for connecting with an oscillator.
Pin no.17: **RA2** Second pin on port A.
Pin no.18: **RA1** First pin on port A.
Clock generator - oscillator
Oscillator circuit is used for providing a MC with a clock.

Types of oscillators:
• PIC16F84 can work with four different configurations of an oscillator.
Note: This pin can be configured as input/output pin

Relationship between a clock and a number of instruction cycles
Reset MC:
Microcontroller PIC16F84 knows several sources of resets:
- Reset during power on, POR (Power-On Reset)
- Reset during regular work by bringing logical zero to MCLR microcontroller's pin.
- Reset during SLEEP regime.
- Reset at watchdog timer (WDT) overflow.
- Reset during at WDT overflow during SLEEP work regime.

Using the internal reset circuit
STATUS Register

- bit 7 **IRP** (Register Bank Select bit)
- bits 6:5 **RP1:RP0** (Register Bank Select bits)
- bit 4 **TO** Time-out ; Watchdog overflow
- bit 3 **PD** (Power-down bit)
- bit 2 **Z** (Zero bit) Indication of a zero result
- bit 1 **DC** (Digit Carry) DC Transfer
- bit 0 **C** (Carry) Transfer