EE-222: Microprocessor Systems

AVR Microcontroller: Program Counter and Program ROM Space

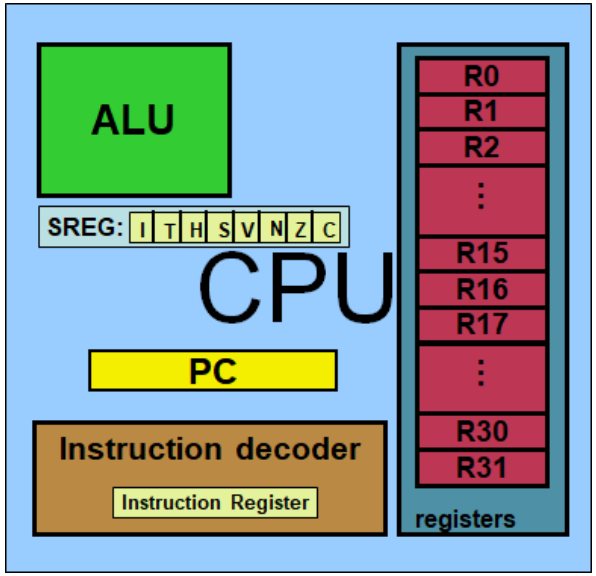
Instructor: Dr. Arbab Latif

NUST

SCHOOL OF ELECTRICAL ENGINEERING & COMPUTER SCIENCE (SEECS)

Program Counter (PC)

- Program Counter (PC)
  - The most important register in the AVR microcontroller
    - Points to the address of the next instruction to be executed
    - Is incremented automatically to point to the next instruction
  - The wider the PC is, the more memory locations it can access
    - For example:
      - 14-bit PC = 16K locations
      - 15-bit PC = 32K locations
      - 16-bit PC = 64K locations



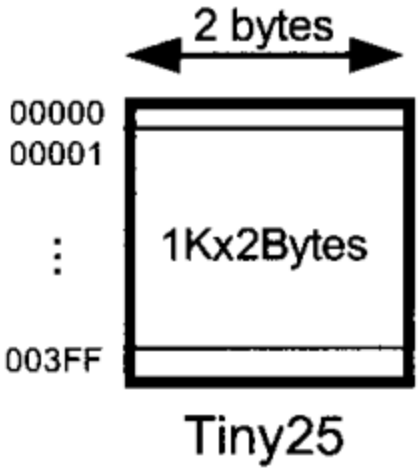
AVR On-Chip ROM Size and Address Space

- In AVR Microcontroller each Flash Memory location is 2-bytes wide
  - Correspondingly the flash is organized as shown in the last column of the table below
  - This arrangement will also change the address range
    - see the second last column in the table below
      - Example in next slide
  - Address 0 is always the first rom address

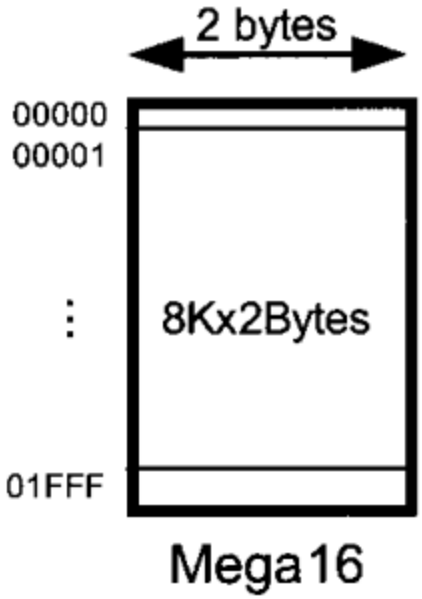
	On-chip Code ROM (Bytes)	Code Address Range (Hex)	ROM Organization
ATtiny25	2K	00000–003FF	1K × 2 bytes
ATmega8	8K	00000–00FFF	4K × 2 bytes
ATmega32	32K	00000–03FFF	16K × 2 bytes
ATmega64	64K	00000–07FFF	32K × 2 bytes
ATmega128	128K	00000–0FFFF	64K × 2 bytes
ATmega256	256K	00000–1FFFF	128K × 2 bytes

ROM Memory Address Range

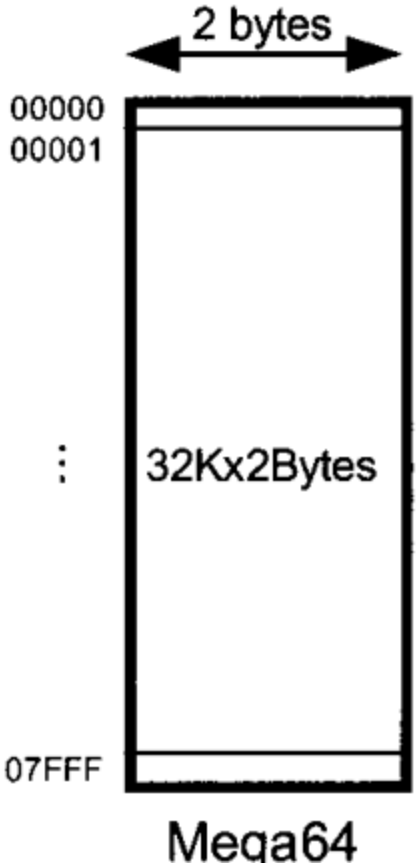
Total ROM Size = 2KB



Total ROM Size = 16KB



Total ROM Size = 64KB



Notice the memory organization and the start and end address

AVR PC

- Program counter in the AVR family can be a maximum of 22-bits
  - Correspondingly, no member of the AVR family can access more than 4M words [do the maths!]

- The ATmega16A Program Counter (PC) is 13 bits wide,
  - thus addressing the 8K program memory locations.

Wake-Up Address

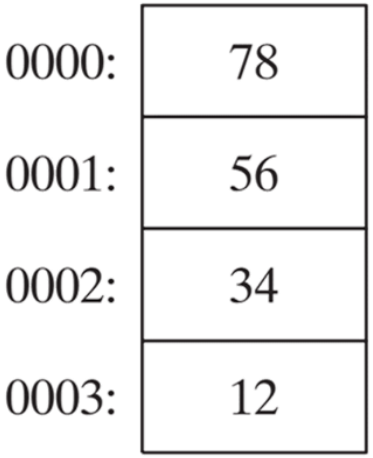
- At what address does the CPU wake-up when power is applied?
  - AVR microntroller wakes up at memory address 0000
    - PC (program counter) has the value of 00000 in it
      - It expects the first opcode must be burned into memory location $00000
      - Achieve this by using the .ORG statement

Endianness

- Endianness is the sequential order in which bytes are arranged into larger numerical values when stored in memory:
  - Little Endian
  - Big Endian

AVR Endianness

Loading the value: 12345678h



- **AVR Microcontroller** store and retrieve data from memory using little-endian order (low to high).

- The **least significant byte is stored at the first** memory address allocated for the data.

Placing Code in Program ROM: Your Lab Program

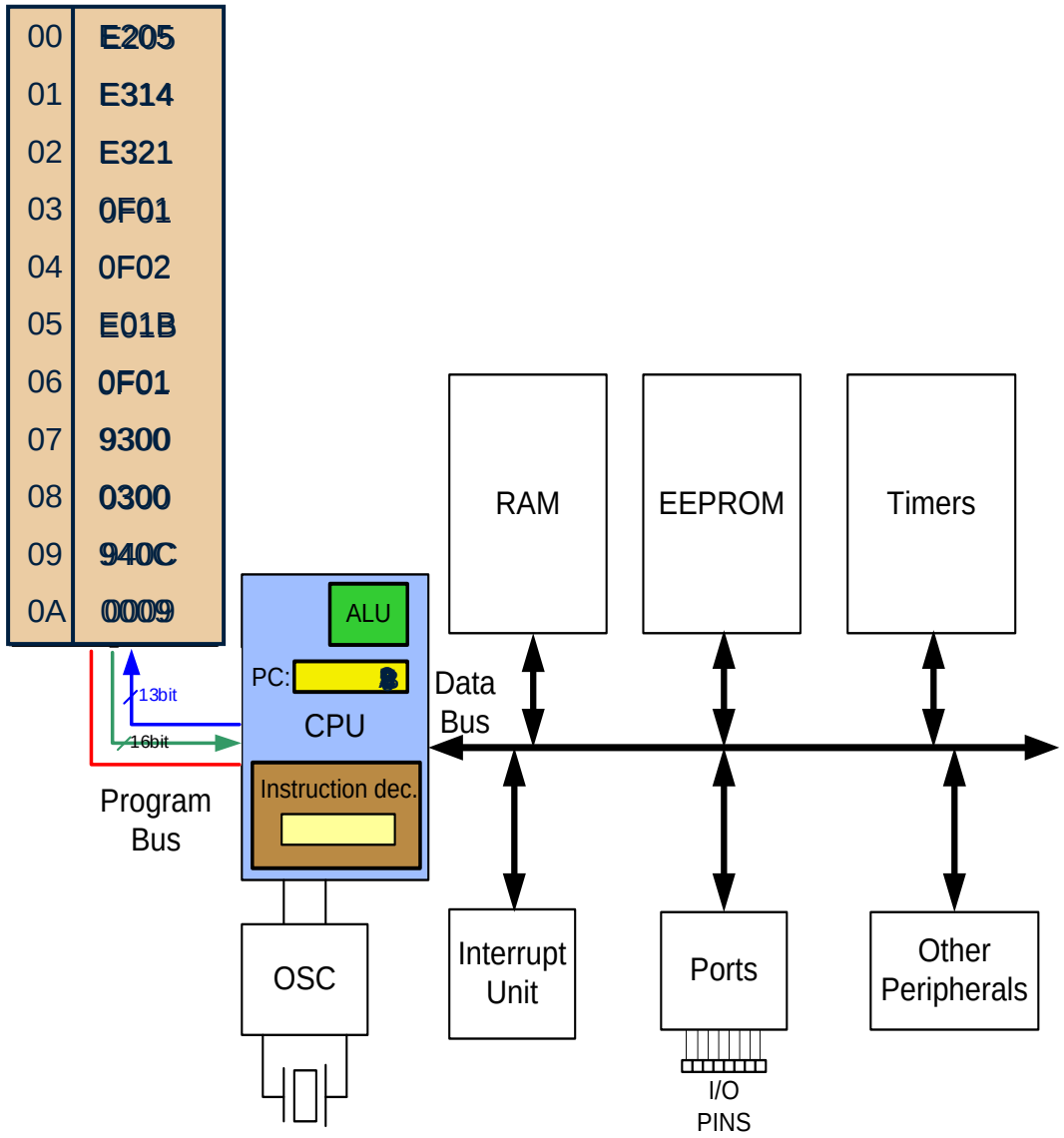
```
000000 ef0f                 ldi R16, 0xFF
000001 ef1f                 ldi R17, 0xFF
                          ; set DDRA as output
000002 bb1a                 out DDRA, R17
                          ; code to toggle LEDs
                          toggler:
000003 5f0f                 subi R16, 0xFF
000004 bf0b                 out 0x3B, R16
000005 c000                 rjmp idle_loop
                          ; delay loop
                          idle_loop :
000006 e13f                 ldi R19, 0x1F
000007 e040                 ldi R20, 0x00
000008 e051                 ldi R21, 0x01

                          idle_loop_0 :
                          idle_loop_1 :
                          idle_loop_2 :
000009 953a                 dec R19
00000a f7f1                 brne idle_loop_2
00000b 954a                 dec R20
00000c f7e1                 brne idle_loop_1
00000d 955a                 dec R21
00000e f7d1                 brne idle_loop_0

00000f cff3               rjmp toggler
```

Flash memory and PC register [ATmega16a]

```
        LDI   R16, 0x25
        LDI   R17, $34
        LDI   R18, 0x31
        ADD   R16, R17
        ADD   R16, R18
        LDI   R17, 11
        ADD   R16, R17
        STS   SUM, R16
HERE:JMP  HERE
```



Reading

- The AVR Microcontroller and Embedded Systems: Using Assembly and C by Mazidi et al., Prentice Hall
  - Chapter-2: Complete

THANK YOU