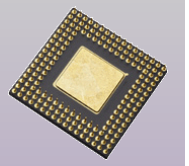


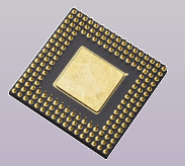
Microprocessors Laboratory

LISHA/UFSC

Prof. Dr. Antônio Augusto Fröhlich
Fauze Valério Polpeta
Lucas Francisco Wanner

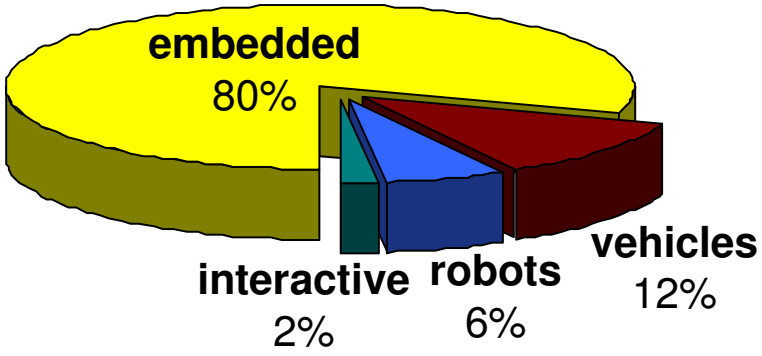
http://www.lisha.ufsc.br/~guto

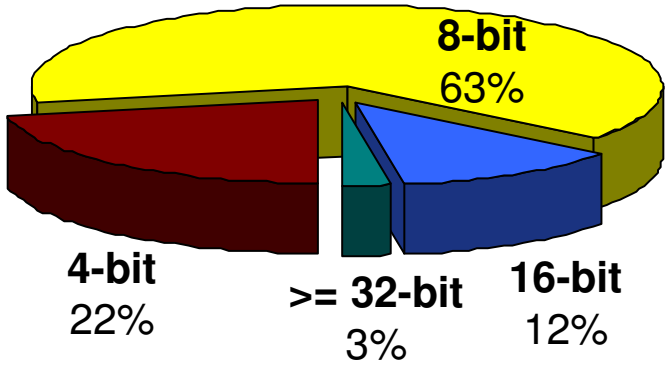
March 2009

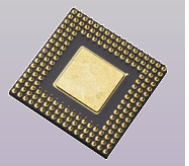


Motivation

Where are the processors?
(Tennenhouse, CACM 43(5):44)





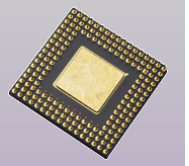


Embedded Systems

"Hardware and software which forms a component of some larger system and which is expected to function without human intervention."

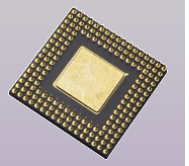
(Foldoc)

- You don't see the computer!
- Typical embedded system
  - Microcontroller with software in PROM
  - Starts running some special purpose application program as soon as it is turned on and will not stop until it is turned off (if ever)



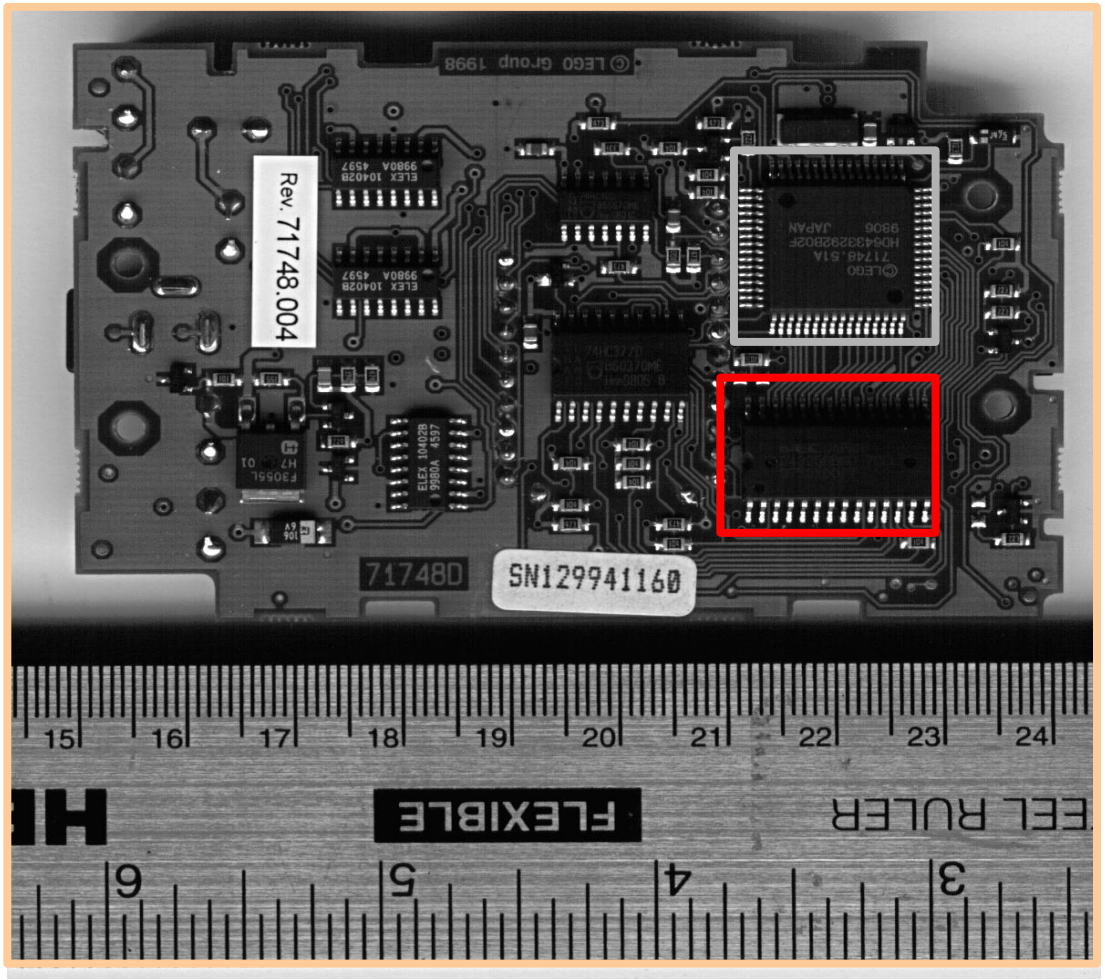
Microprocessors X Microcontrollers

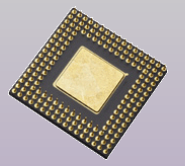
- Microprocessor
  - A computer whose entire CPU is contained on one (or a small number of) integrated circuits
  - Characterized by
    - Instruction set (RISC / CISC)
    - Address and data bus width
    - Clock rate
- Microcontroller
  - A microprocessor on a single integrated circuit intended to operate as an embedded system. As well as a CPU, a microcontroller typically includes small amounts of RAM and PROM and timers and I/O ports



Sample Embedded System: LEGO RCX

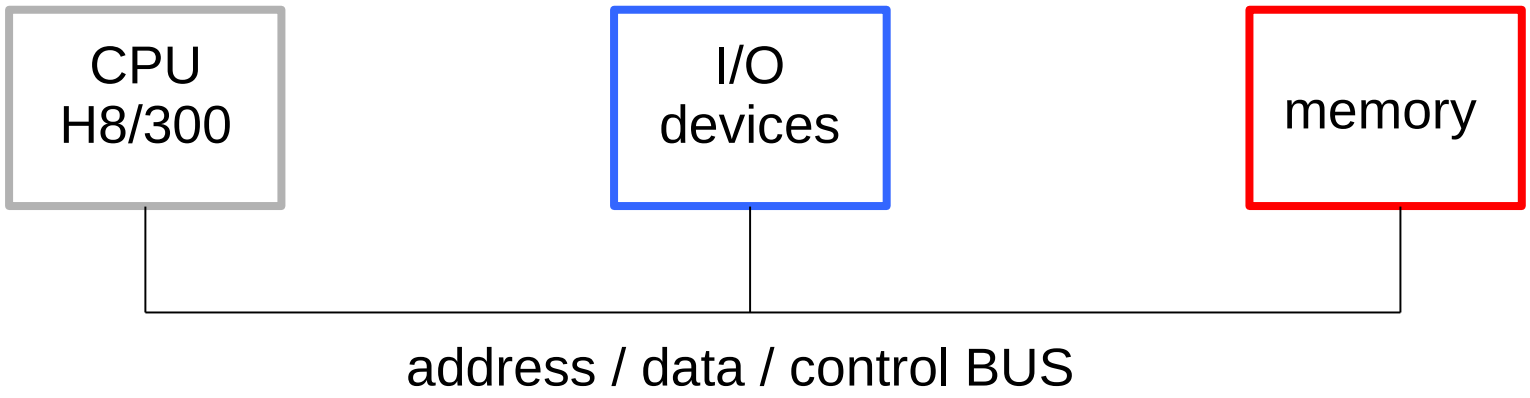
- LEGO RCX
  - Programmable hardware module
  - Interface to I/O devices (sensors and actuators)
  - Hitachi H8/3292 microcontroller

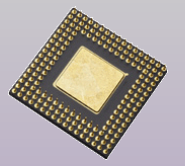




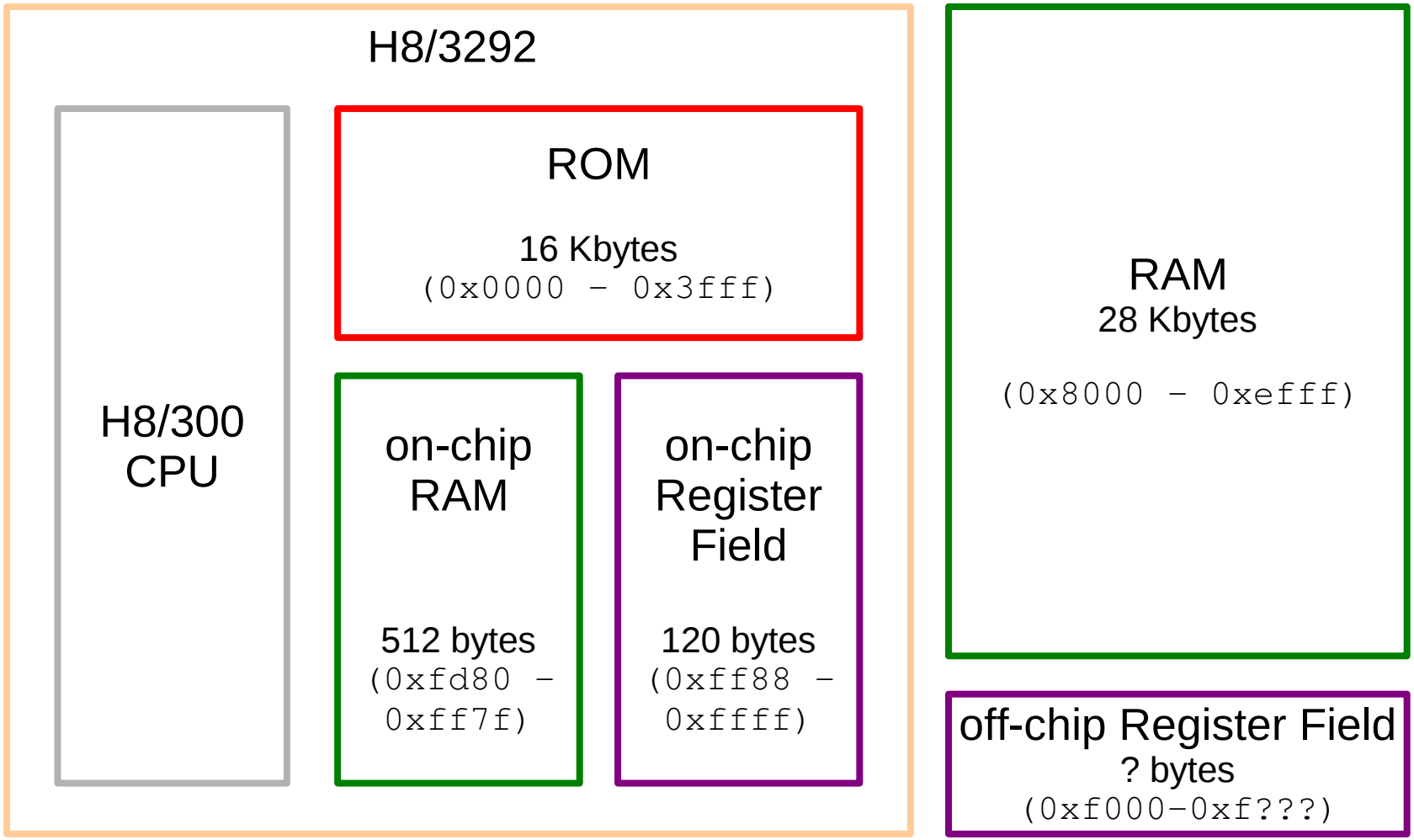
Sample Microcontroller: Hitachi H8/300

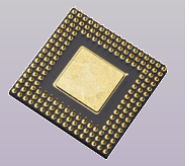
- H8/300 CPU
  - RISC
  - 8-bit data
  - 16-bit address space
  - 8 x 16-bit GP registers
    - r0 => function return
    - r7 => stack pointer
  - 16 Mhz clock





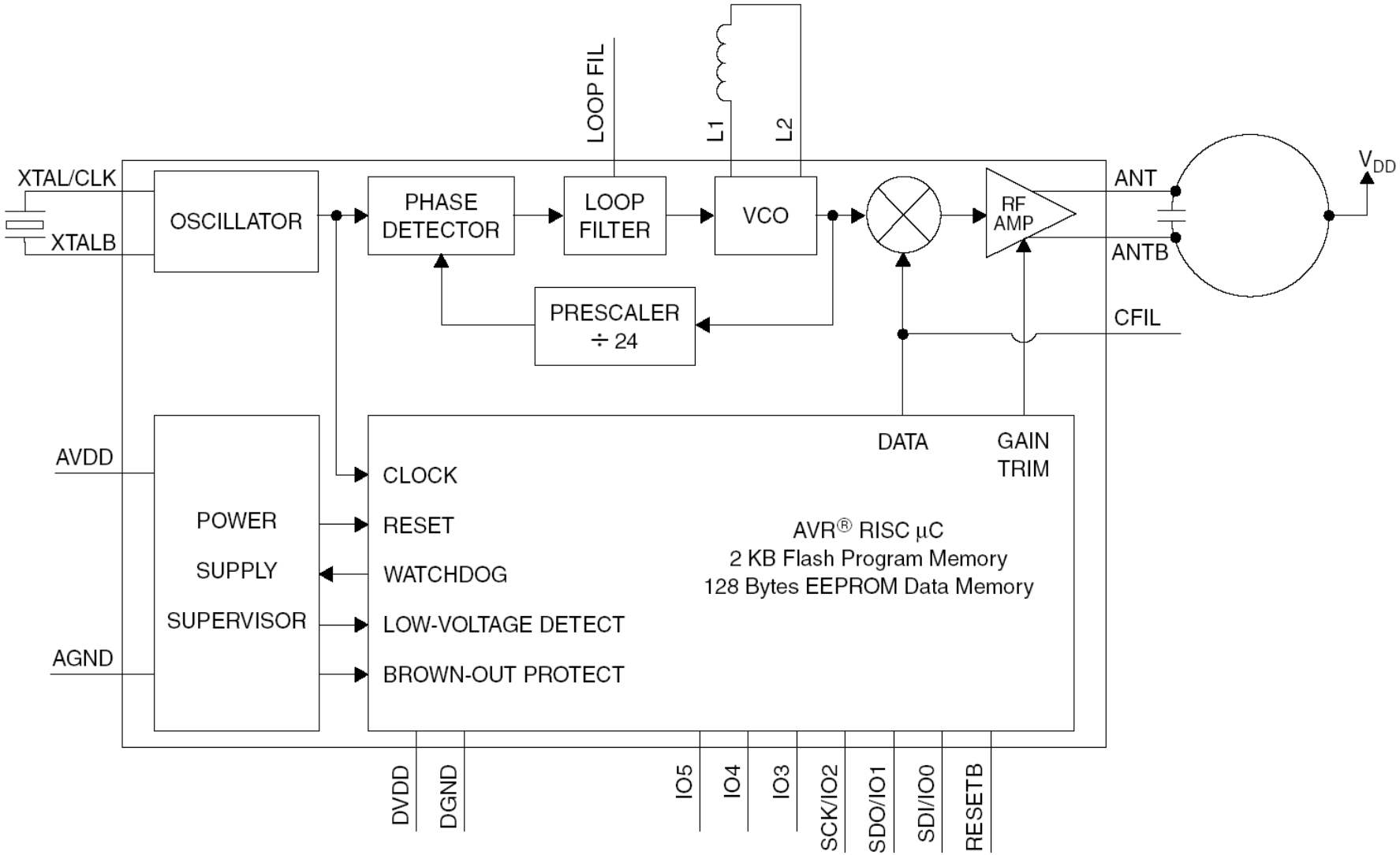
Sample Microcontroller: Hitachi H8/300

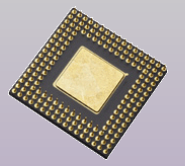




Microprocessors Laboratory

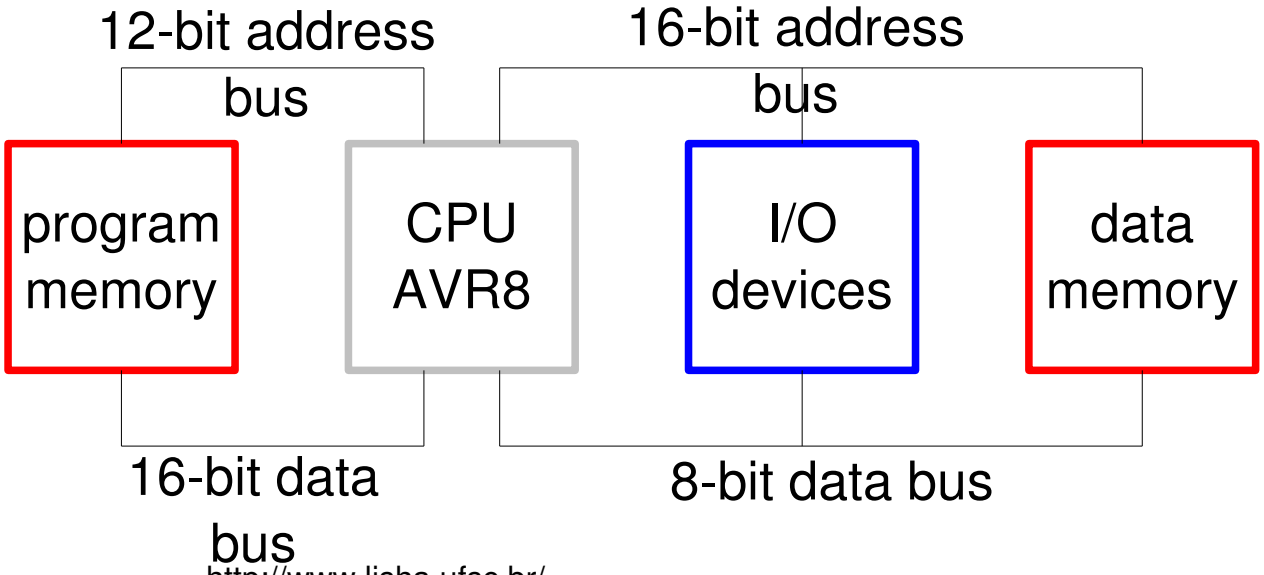
Sample Embedded System: AT86RF401

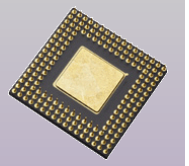




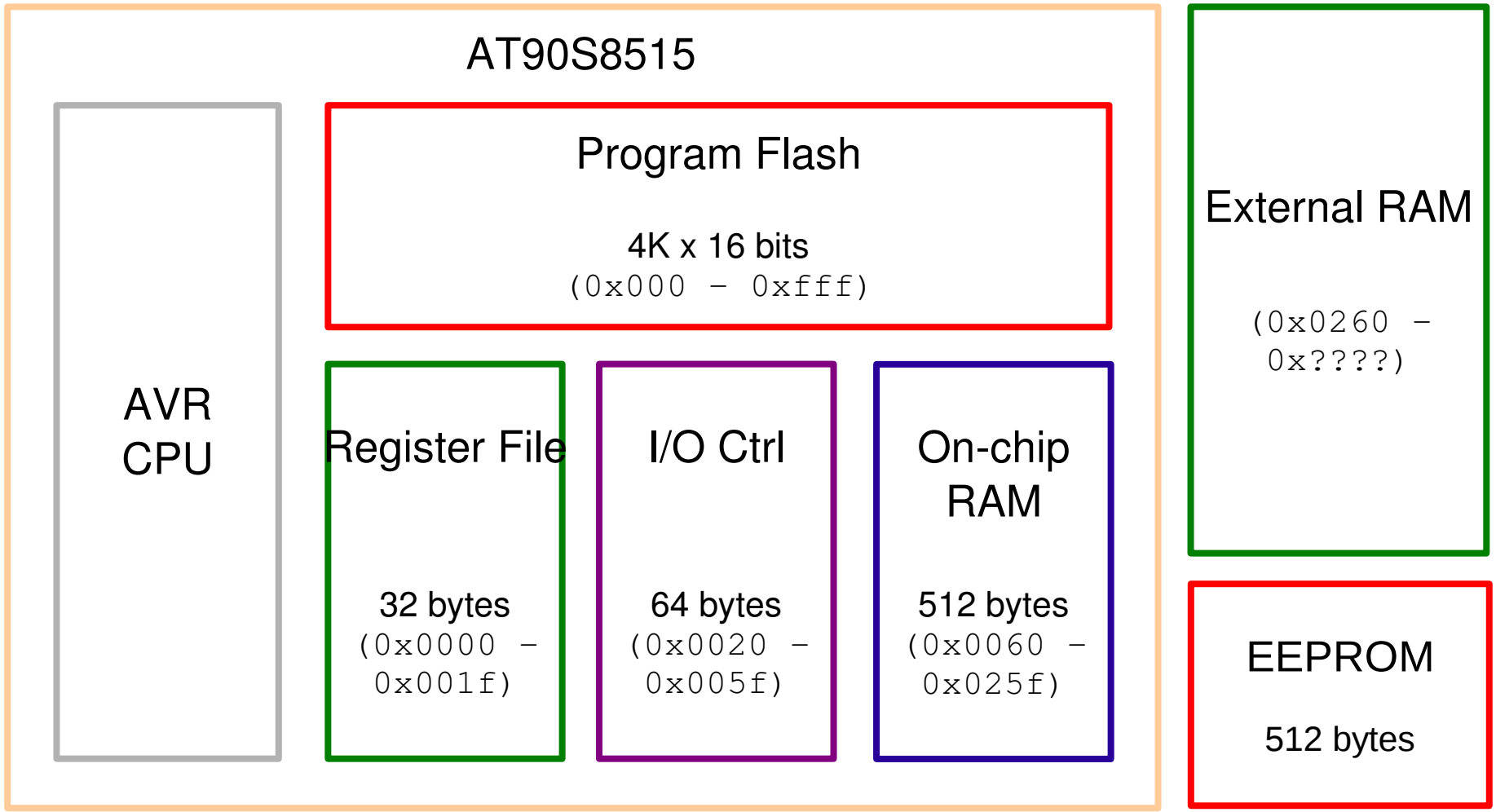
Sample Microcontroller: AVR AT90S

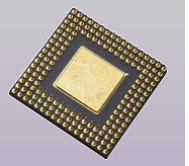
- AVR CPU
  - RISC
  - 8-bit data
  - Harvard architecture
    - 16-bit data address space
    - 12-bit program address space
  - MCU
    - UART
    - SPI
    - A/D
    - timers
  - 32 x 8-bit GP registers
    - 3 16-bit pointers: X (r26:27), Y (r28:29), Z (r30:31)
  - Memory-mapped I/O Registers
  - 8 MHz clock





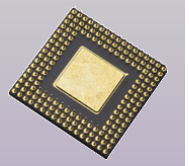
Sample Microcontroller: AVR AT90S





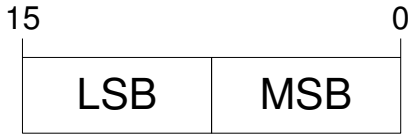
AVR Instruction Set

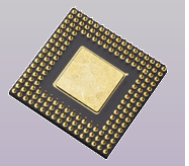
- Instructions are 16 or 32 bits wide
  - Program memory is word-addressed
- Instructions take 1-4 clock cycles
  - Most take one
- ALU instructions
  - `add, subi, and, inc, mul, ...`
- Branch instructions
  - `rjmp, ljmp, rcall, ret, reti, brge, ...`
- Data transfer instructions
  - `mov, ld, st, lpm, push, pop`
- Bit and bit-test instructions
  - `lsl, swap, cli, ...`



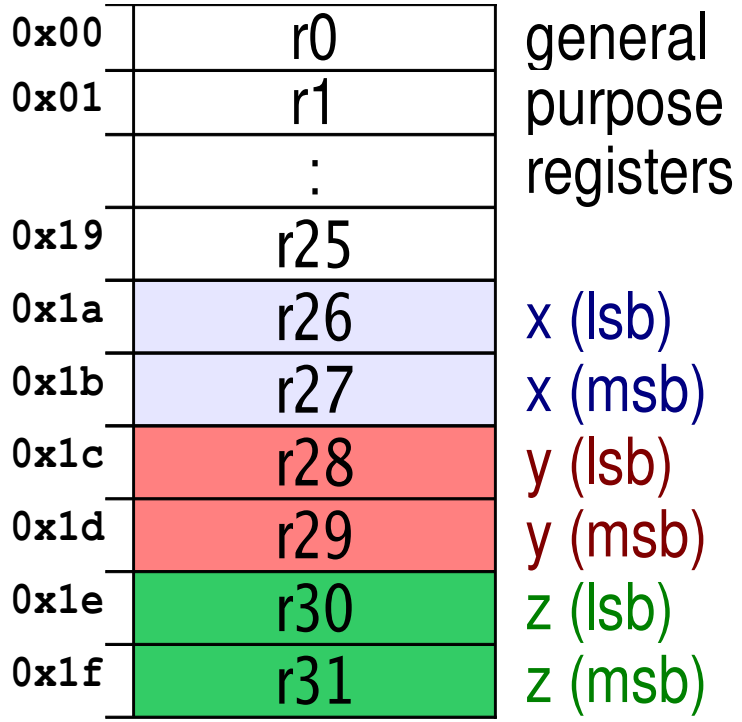
AVR Data Types

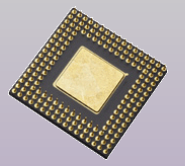
- Data Types
  - Bytes (8 bits)
  - Words (16 bits)
- Little-endian





AVR Registers





AVR Data Addressing Modes

- Register direct

```
clr   r0              ; r0 is cleared
add   r0, r1          ; r0 = r0 + r1
```

- I/O direct

```
in    r16, mcucr      ; r16 = mcucr (I/O 0x35)
```

- Memory direct

```
lds   r0, 1234        ; r0 = *((unsigned char *)0x1234)
```

- Memory indirect with displacement

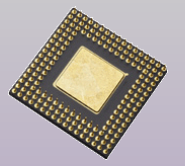
```
ldd   r0, y + $3F     ; r0 = y[$3F]
```

- Memory indirect (pre-decrement / post-increment)

```
ld    r0, x+          ; r0 = *x++
```

- Constant addressing using LPM (program memory)

```
lpm                   ; r0 = Program_Memory[z]
```



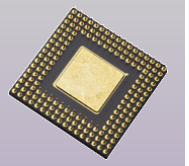
AVR Program Addressing Modes

- Indirect

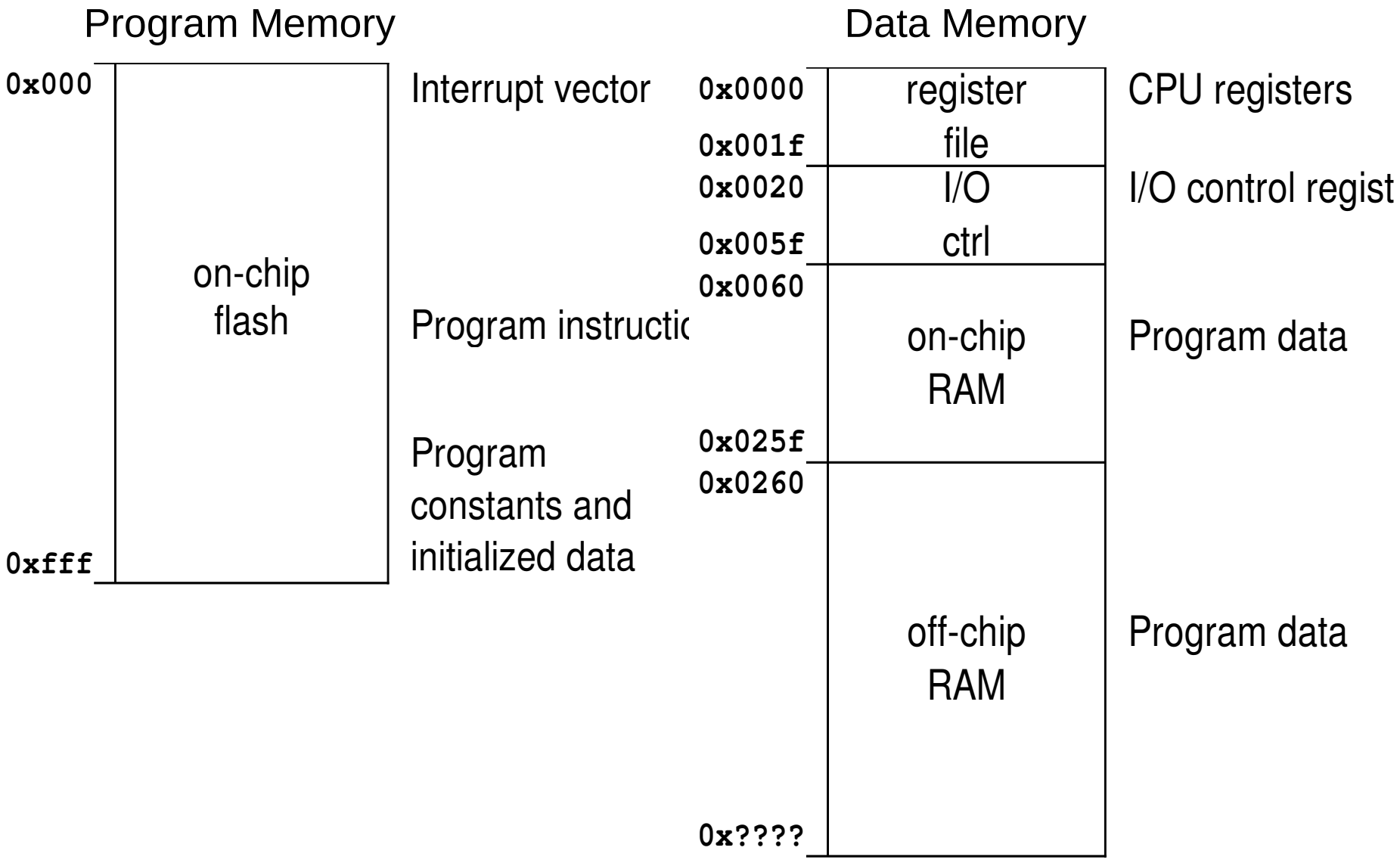
```
ijmp        ; PC = z
```

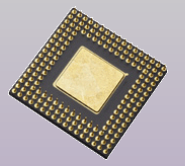
- Relative

```
rjmp  $20   ; PC = PC + 20 + 1
```



AVR AT90S Memory Layout

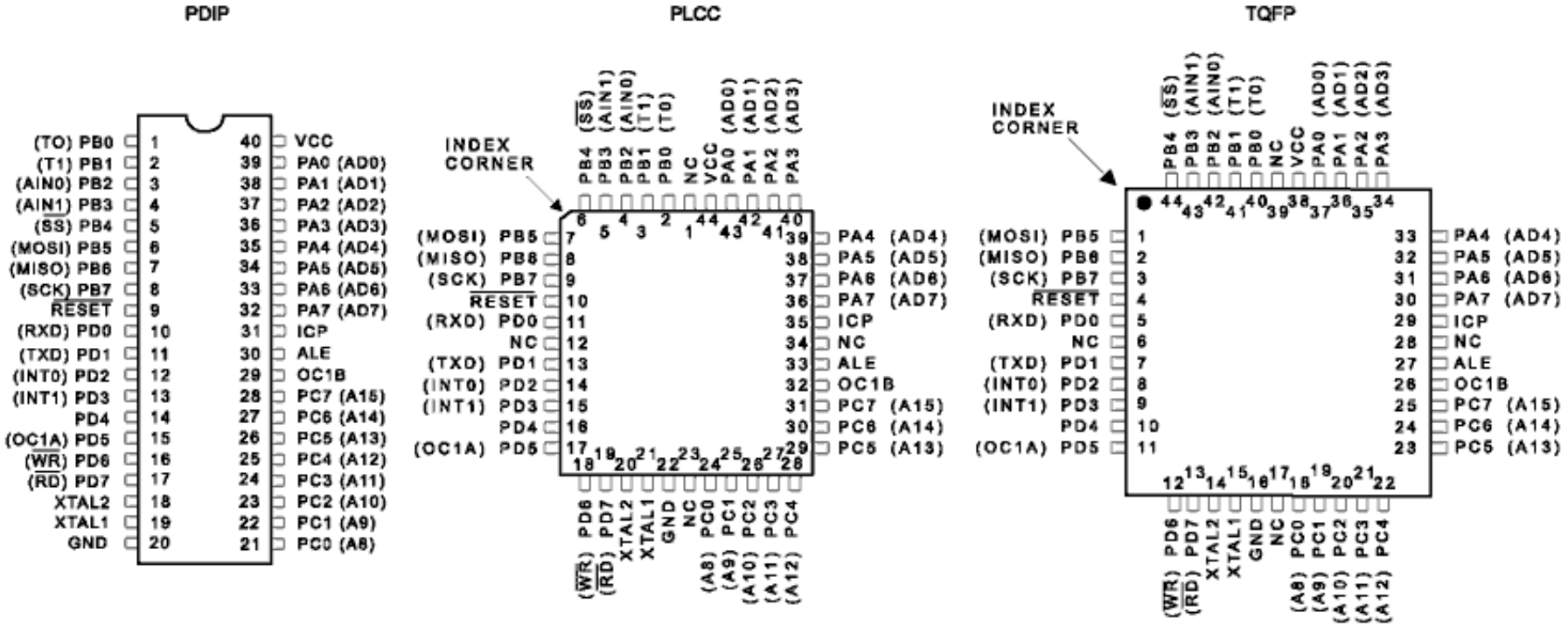


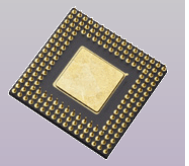


Microprocessors Laboratory

AVR AT90S8515 I/O

- 40-44 pins
  - 4 GPIO ports
  - VCC, GND, RESET, XTAL, ...





AVR I/O and Peripherals

- Parallel ports
  - CPU pins / GPIO
- Timers / counters
  - Generic (control sequences, OS ticks, ...)
  - Watchdog
- Serial ports
  - UART
- Serial Peripheral Interface (SPI)
- I2C bus
- DMA controllers
- A/D and D/A converters