# Microcontroller and microprocessor architecture

The processing components used for computing and control tasks can be divided into two broad categories, **microcontrollers and microprocessors**.

**Microcontrollers** are small computing devices on a single chip that contain one or more processing cores, with ROM (*Read-Only Memory*) and RAM (*Random Access Memory*) memory embedded alongside programmable special and general purpose input and output (I/O) ports and other on-chip peripherals and support circuits. They are used especially in control applications where only specific repetitive tasks need to be performed.

**Microprocessors** on the other hand are general purpose computing devices which incorporate all the functions of the central processing unit on a chip but do not include peripherals like memory and I/O ports. They are dependent on external peripheral circuits to work.

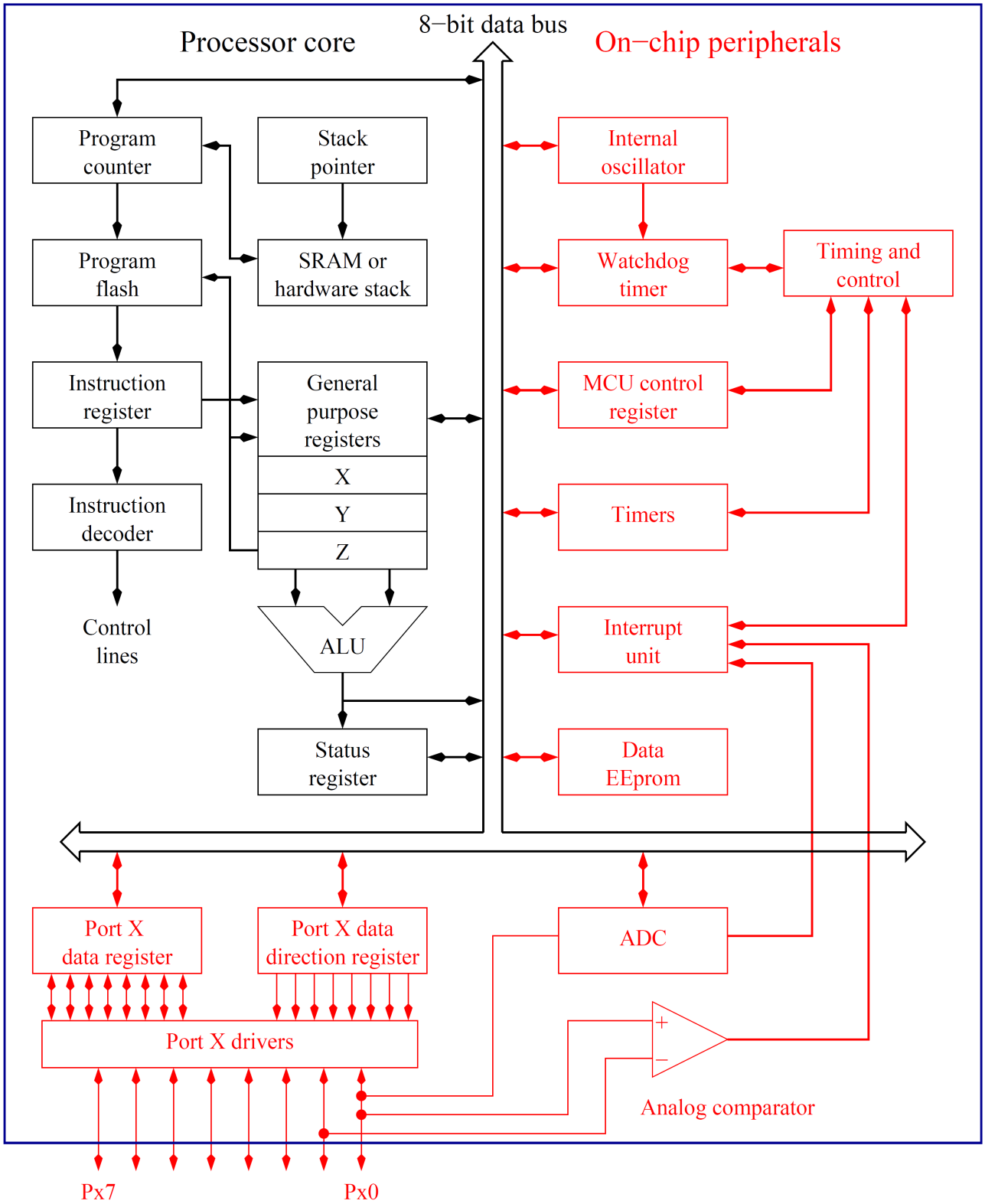
## AVR architecture

We will look at the internal architecture of the ATMEL AVR ATtiny and ATmega series of 8-bit microcontrollers as an example.
AVR microcontrollers are available as single chip devices in package sizes from 8 pins (external connections) up to 100 pins. They are low-power CMOS 8-bit RISC (*Reduced Instruction Set Computer*) microcontrollers based on a Harvard architecture with separate memories and buses for program and data. Instructions in the program memory are executed with a single level pipelining. While one instruction is being executed, the next instruction is prefetched from the program memory. This concept enables instructions to be executed in every clock cycle. By executing powerful instructions in a single clock cycle, AVRs achieve throughputs up to ten times faster than conventional CISC *(Complex Instruction Set Computer)* microcontrollers, approaching 1 MIPS *(Million Instructions Per Second)* per MHz.

The program memory of AVR microcontrollers is located in in-system reprogrammable non-volatile flash memory, the size varies from 512 bytes to 64 Kbytes or more.
In the smallest devices, there is no data memory, programs use registers only. The size of on-chip data memory (SRAM, *static RAM*) varies from 0 to 8 Kbytes.
Most processors also have EEPROM *(Electrically Erasable Programmable Read-Only Memory)* memory, the size varies from 0 to 4 Kbytes.
The C compiler can only be used for devices with SRAM data memory.

Internally, the AVR microcontrollers have:
- 16 bit instruction word
- a minimum 16-bit program counter (PC)
- 32 8-bit registers, r0 to r31
- separate instruction and data memory
- 64 registers dedicated to I/O and control
- general purpose registers and I/O registers are mapped into the data memory
- AVR microcontrollers are externally interruptible, interrupt source is programmable
- most instructions execute in one clock cycle

# Typical ATMEL AVR device



The black part on the figure above contains the **processor core** (CPU, *Central Processing Unit*). The main function of the processor core is to ensure correct program execution. The CPU must therefore be able to access memories, perform calculations, control peripherals, and handle interrupts.

The main part of the processor core is the **ALU (*Arithmetic Logic Unit*)**. The ALU executes arithmetic and logic operations between registers or between a constant and a register. Single register operations can also be executed in the ALU.

Register File contains 32 × 8-bit **general purpose registers** with a single clock cycle access time. In a typical ALU operation, two operands are output from the Register File, the operation is executed, and the result is stored back in the Register File

**Status Register** contains information about the result of the most recently executed instruction.

The **Stack** is mainly used for storing temporary data, for storing local variables and for storing return addresses after interrupts and subroutine calls. The **Stack Pointer Register** SP always points to the top of the Stack.

The program is stored in the flash memory, which is addressed by the **Program Counter** (PC). The PC is 15/16 bits wide, thus addressing the 32/64K program memory locations. Program instructions are written into **Instruction Register** and decoded in the **Instruction Decoder**.

The red part on the figure above contains on-chip peripherals and support circuits.
**Support circuits** are:
- Clock oscillators
- Timing circuits
- The watchdog
- MCU (MicroController Unit) control registers
- Interrupt subsystem
- Data EEPROM.

Typical AVR **peripherals** are:
- Ports with programmable I/O lines and port drivers
- Two 8-bit and one 16-bit Timer/Counters with separate prescaler and compare mode and with PWM (Pulse Width Modulation) Channels
- 8-channel 10-bit ADC (Analog Digital Converter)
- Programmable serial USART (Universal Synchronous/Asynchronous Receiver and Transmitter)
- Master/slave SPI (Serial Peripheral Interface) serial interface
- Byte-oriented 2-wire serial interface
- On-chip analog comparator
- Temperature measurement circuits