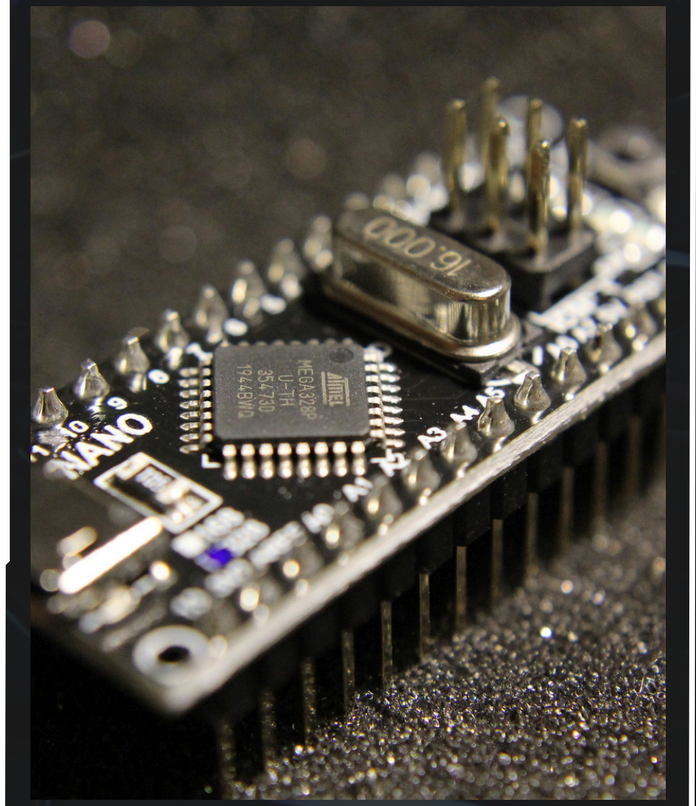
EMBEDDED **SYSTEMS**

The foundation of modern innovation, connecting the world through digital systems.



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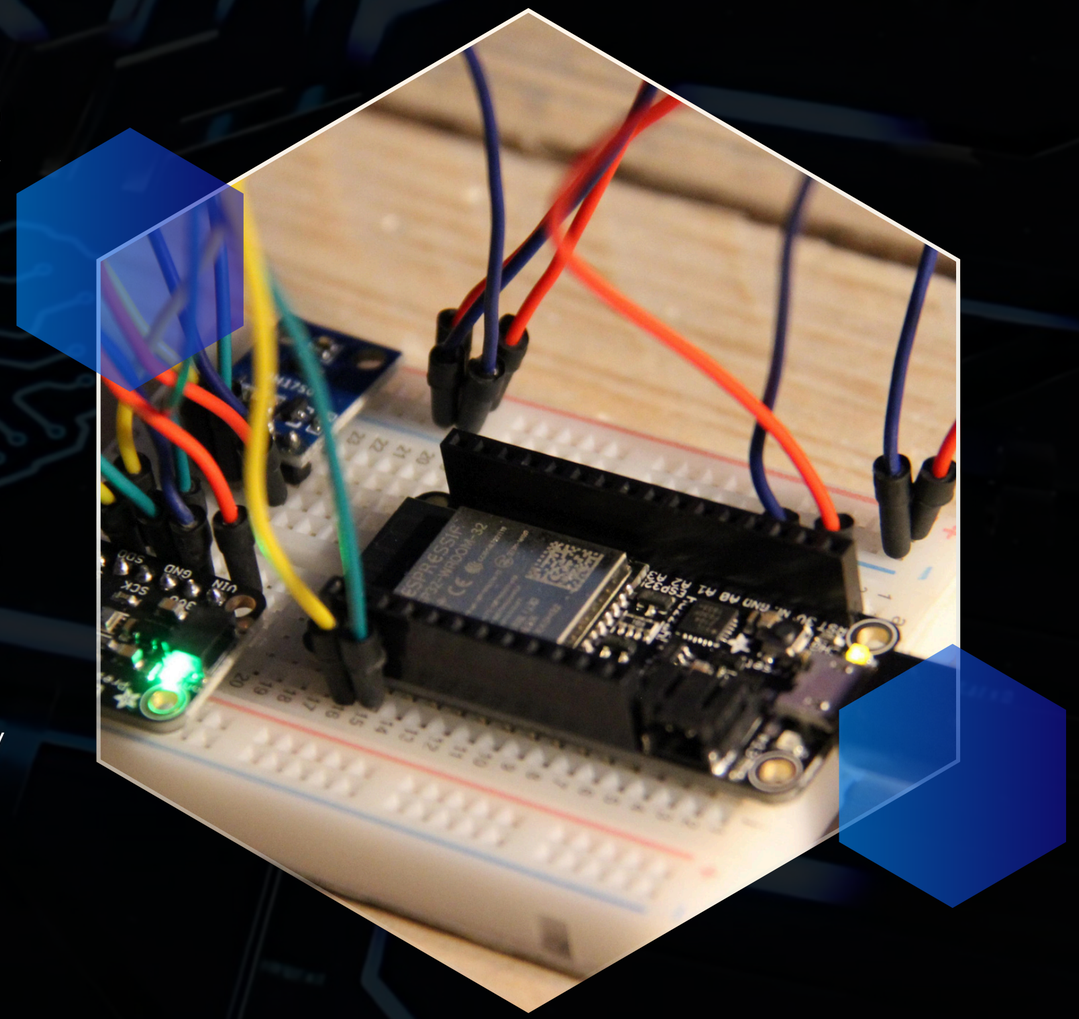
ABOUT **MICROCONTROLLER UNIT**

A Microcontroller Unit (MCU) is a compact integrated circuit designed to perform specific control functions within an embedded system. It typically combines a processor (CPU), memory (RAM and ROM/Flash), and input/output (I/O) peripherals on a single chip, enabling it to operate independently and efficiently in real-time applications. MCUs are widely used in various electronic devices, such as home appliances, automotive systems, medical equipment, and industrial machines, where they manage tasks like reading sensor data, controlling actuators, and communicating with other components. Their low power consumption, cost-effectiveness, and versatility make them ideal for applications that require dedicated, programmable control.



MCU
ARCHITECTURE

- **Central Processing Unit**
- **Memory and storage devices**
- **Input and output peripherals**
- **Timers and Counters**
- **Bus System**
- **Communication Interfaces**
- **Interrupt Controller**
- **ADC/DAC Modules**
- **Clock System (Oscillator/Crystal)**

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ARCHITECTURE

Von Neumann Architecture

is called “one memory system” because it uses a single memory space and bus for both instructions and data. It fetches instructions and data one at a time and simpler design and easier programming but it is slower due to the "bottleneck" of using one bus like some early ARM designs and older 8051 microcontrollers.

Harvard Architecture

Is a hybrid model that separates instruction and data memory but allows flexibility in access. It enables access to data memory and program memory with optimized control. It balances performance and simplicity. For example : Many modern ARM Cortex-M series microcontrollers.

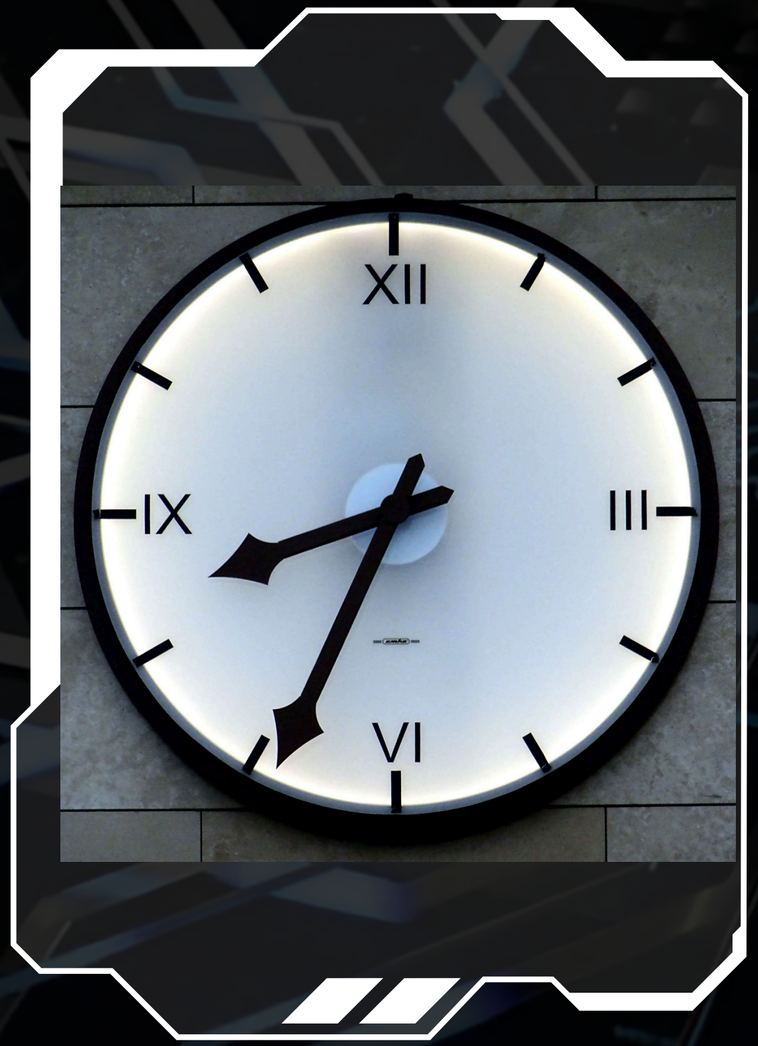
ACCESS TECHNIQUES

Memory-mapping

Memory mapping in Von Neumann architecture depends on addressing every device which means giving every device some locations which are unique.
It uses assembly instructions like LDR for load and STR for store.
It consumes address space and may require decoding logic to distinguish between different devices.

Port Mapping

Port mapping used in Harvard architecture. The devices are accessed through special instructions and have a separate address space from memory.
Its pros are that the memory address space is preserved (not used for I/O) and simple hardware decoding for I/O.
But its cons that it requires special instructions for I/O access and is less flexible and may complicate programming.



CLOCK **SYSTEM**

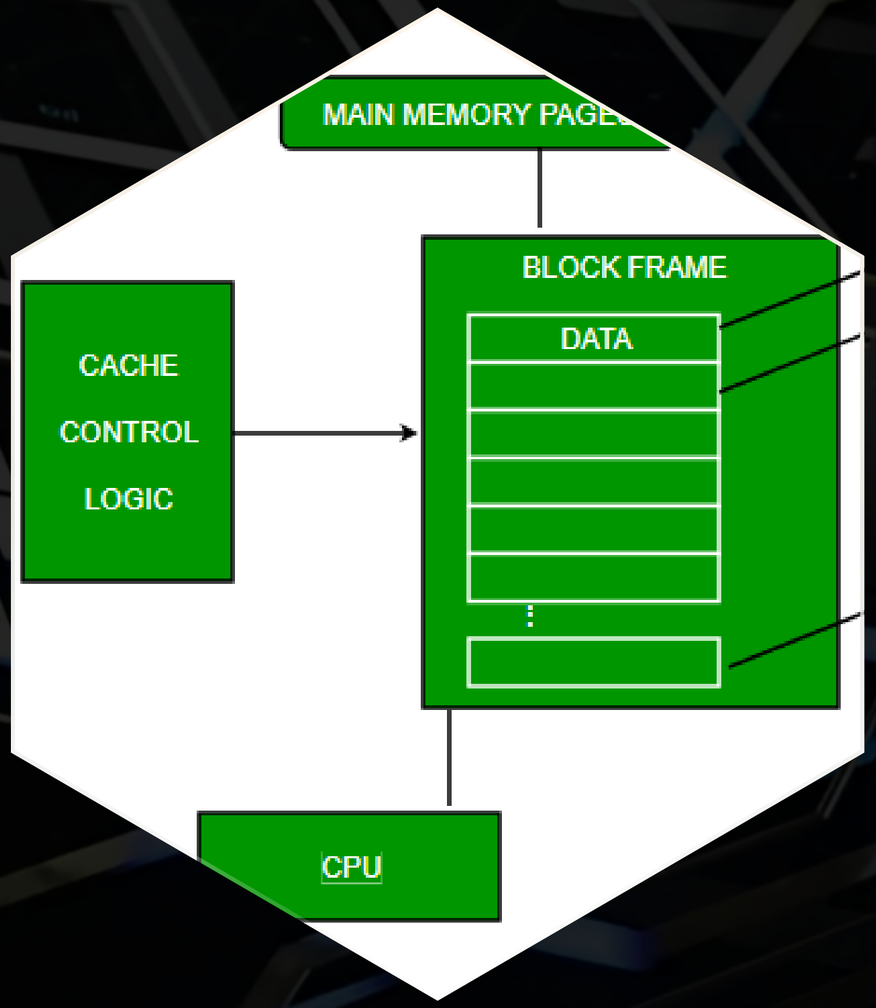
A clock is responsible for generating the timing signals that coordinate all operations inside the chip. Every instruction, peripheral action, data transfer, or timing-sensitive task depends on the clock signal to occur at precise intervals.

Electrical

RC-Oscillator

Mechanical

Ceramic / Crystal



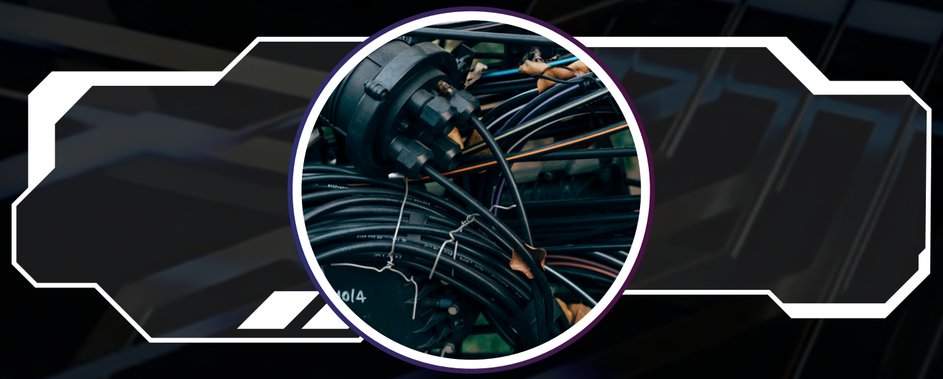
MEMORY **MAPPING**

Memory mapping is the technique of assigning specific memory address ranges to various system components so the CPU can read from and write to them using standard memory access instructions.

- Enables direct communication between CPU and hardware.
- Simplifies programming by using standard load/store instructions.
- Crucial for managing RAM, ROM, stack, heap, and device registers.
- Helps design efficient embedded systems and OS memory models.

BUS INTERFACES

A Bus Interface is the communication bridge between the processor (CPU) and other components like memory, input/output devices, or peripherals. It manages how data, addresses, and control signals are transferred across the system’s internal bus.



- **AHB (AMBA High-performance Bus)**
- **APB (Advanced Peripheral Bus)**
- **AXI (Advanced eXtensible Interface)**
- **Internal Data Bus**
- **Address Bus**

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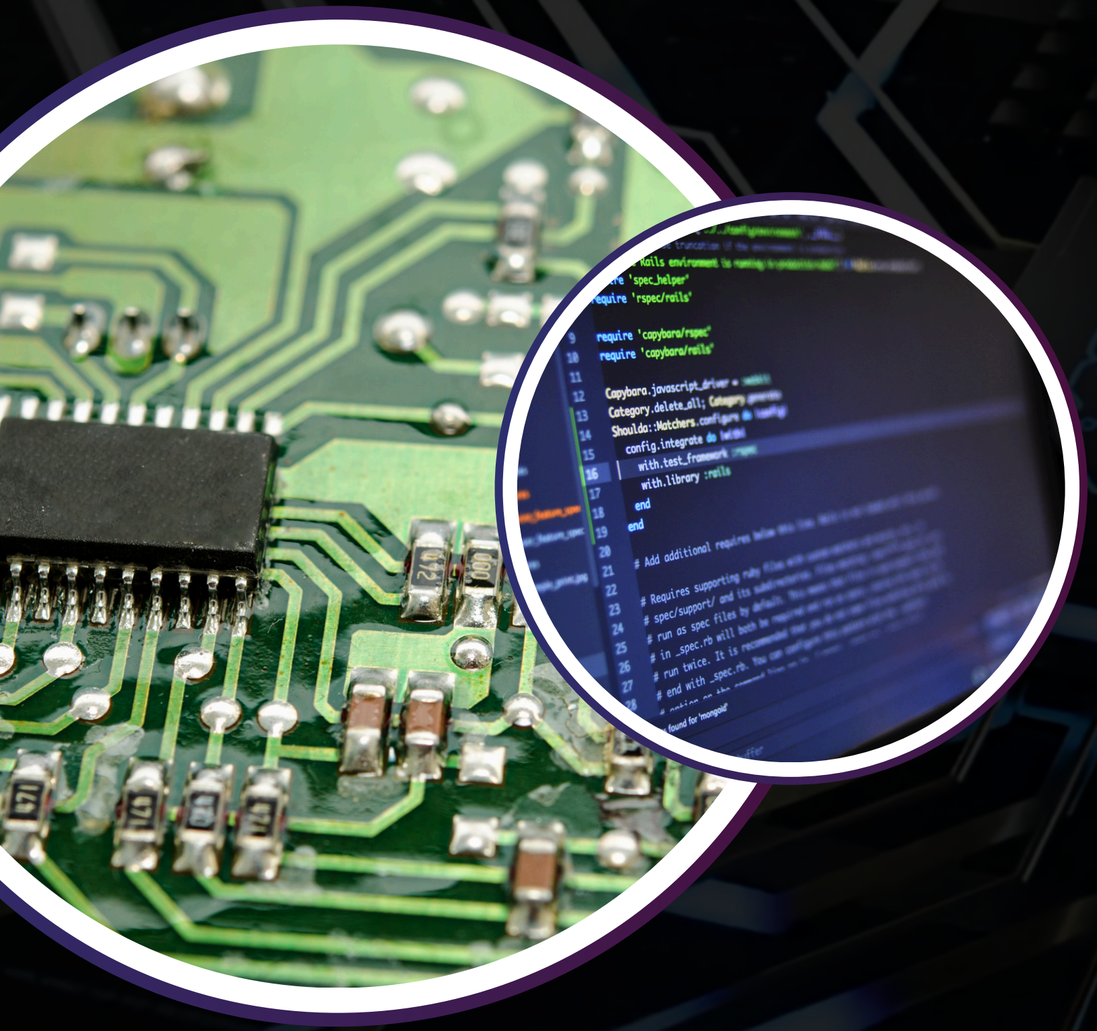

AMBA

Advanced Microcontroller Bus Architecture (AMBA) is an open-standard, on-chip interconnect protocol developed by ARM to efficiently connect the CPU core with memory, peripherals, and other system components in SoCs (System on Chips) and MCUs. It is widely used in ARM-based microcontrollers like STM32, NXP Kinetis, LPC, and others

The differences between buses are :-

- Bandwidth which is the number of bits per second can be transferred through that bus. (frequency)
- Latency is the time required to confirm your command or permission or what you have ordered to be done. (transaction time for example).

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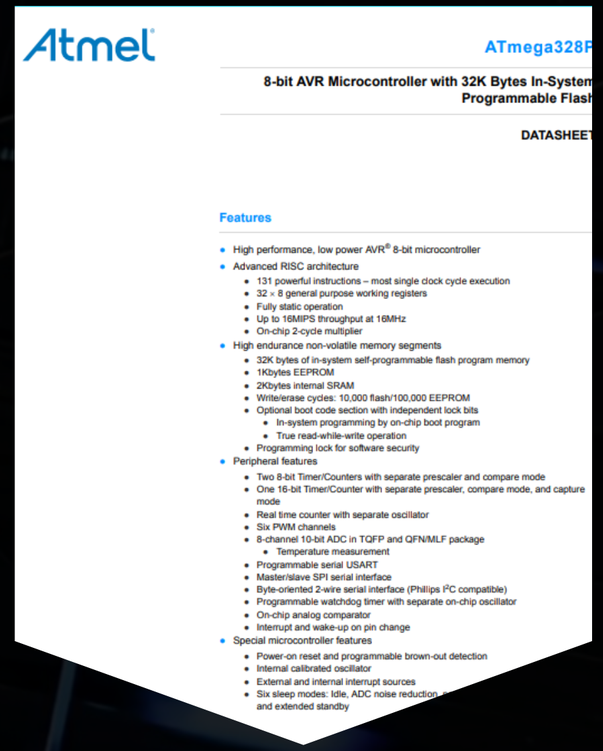
MCU
DATASHEET AND SPECIFICATIONS


Atmel

ATmega328P

8-bit AVR Microcontroller with 32K Bytes In-System Programmable Flash

DATASHEET

Features

- High performance, low power AVR® 8-bit microcontroller
- Advanced RISC architecture
  - 131 powerful instructions – most single clock cycle execution
  - 32 × 8 general purpose working registers
  - Fully static operation
  - Up to 16MIPS throughput at 16MHz
  - On-chip 2-cycle multiplier
- High endurance non-volatile memory segments
  - 32K bytes of in-system self-programmable flash program memory
  - 1Kbytes EEPROM
  - 2Kbytes internal SRAM
  - Write/erase cycles: 10,000 flash/100,000 EEPROM
  - Optional boot code section with independent lock bits
    - In-system programming by on-chip boot program
    - True read-while-write operation
  - Programming lock for software security
- Peripheral features
  - Two 8-bit Timer/Counters with separate prescaler and compare mode
  - One 16-bit Timer/Counter with separate prescaler, compare mode, and capture mode
  - Real time counter with separate oscillator
  - Six PWM channels
  - 8-channel 10-bit ADC in TQFP and QFN/MLF package
    - Temperature measurement
  - Programmable serial USART
  - Master/slave SPI serial interface
  - Byte-oriented 2-wire serial interface (Philips I²C compatible)
  - Programmable watchdog timer with separate on-chip oscillator
  - On-chip analog comparator
  - Interrupt and wake-up on pin change
- Special microcontroller features
  - Power-on reset and programmable brown-out detection
  - Internal calibrated oscillator
  - External and internal interrupt sources
  - Six sleep modes: Idle, ADC noise reduction, and extended standby

Block Diagram

The internal connections between components like CPU, Memory and other peripherals.

Pin Configuration

Showing all the pins and their functionalities.

Memory Map

Electrical Characteristics

Operating voltage, maximum current and clock speed.

THANK YOU!

Thank you for exploring computer technology—a field shaping our future!