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Real Time Embedded Systems

Research 1

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When it comes to computers, the processor is the one that is playing the most important role. Processors are the brain of any system such as computers, laptops, smartphones, embedded systems, etc. The ALU (Arithmetic Logic Unit) and CU (Control Unit) are the two parts of the processors.

There are many types of processors for different applications but the question is that when to choose which processor.

As a first approach to the problem, we are going to pick some popular processors in today's world and take into consideration their important characteristics effecting our selection.

There are three steps for a processor to be constructed.
The first step is ISA or architecture which incorporates characteristics such as number of registers, data types/sizes, addressing modes, instructions complexity, branch/jump/function call handling, exception handling, instruction format/size/regularity and ... . This step forms the first fraction of iron law ($\frac{\text{Instructions}}{\text{Program}}$).
The second step is implementation or μarchitecture. It includes attributes like logical structure, pipelining, functional units, caches, physical registers and so on. This step forms the second fraction of iron law ($\frac{\text{Cycles}}{\text{Instruction}}$).
The last step is realization or chip related parts which incorporates chip/system design, physical structure for the implementation, gates, cells, transistors, interconnection and etc. This step forms the third fraction of iron law ($\frac{\text{Time}}{\text{Cycle}}$).
According to the explanation above, by knowing the processors' iron law we will be able to assess and compare them to a good extent.

AMD Ryzen 9 5900X

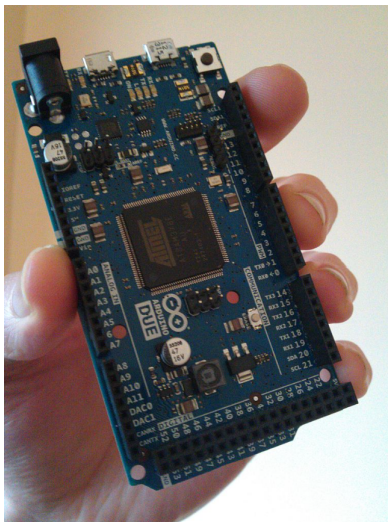
- The most popular processor based on the total number of benchmark results submitted across all tests in 30 days
- Class: Desktop
- Socket : AM4
- Price: [347 - 600] USD
- Cores: 12
- Threads: 24
- Cache size L3: 64 MB
- Clock Speed: 3.7 GHz
- Turbo Speed: 4.8 GHz

- Thermal Design Power (TDP): 105 W
- Included Thermal Solution: No
- Maximum Temperature: 90°C
- Manufacturing Process: 7 nm

Integer Math	144,667 MOps/Sec
Floating Point Math	77,655 MOps/Sec
Find Prime Numbers	249 Million Primes/Sec
Random String Sorting	53 Thousand Strings/Sec
Data Encryption	31,434 MBytes/Sec
Data Compression	491.7 MBytes/Sec
Physics	2,020 Frames/Sec
Extended Instructions	32,924 Million Matrices/Sec
Single Thread	3,471 MOps/Sec

Advanced RISC Machine (ARM)

- Popular ARM-based processors include ARM7, ARM9, ARM11 and cortex. ARM provides compiler, debugger and software development kit tools, along with a complete hardware description of the ARM core, to interested parties.

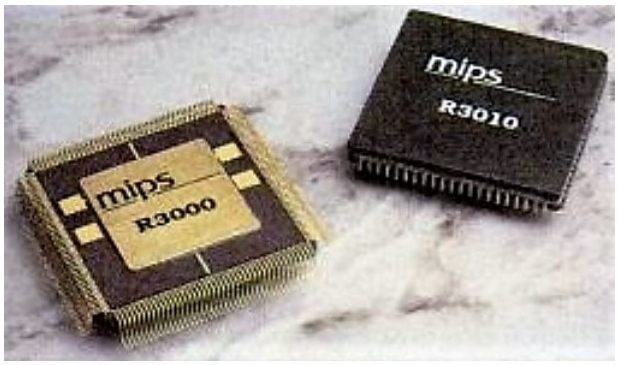


- Very small size → Perfect fit for small size devices
- Less power consumption
- Reduced complexity in its circuits
- High clock speed
- Multiprocessing Systems: Can be used in case more than one processors are used to process information.
- Load/store-based architecture

- Fixed 32-bit instruction set → Allows time for fetching future instructions before executing present instruction.
- Pipelining: The pipeline advances one step at a time to increase throughput.
- One cycle execution time (CPI = 1 cycle): ARM processor is optimized for each instruction on CPU, Easy decoding.
- Large number of registers (16x32 bit register file) → Prevent large amount of memory interactions, Registers contain data and addresses → Local memory store for all operations
- Power-indexed addressing modes
- Tightly Coupled Memory → Very fast response time, Low latency, Can be used in cases of cache memory being unpredictable.
- Memory Management and Memory Protection units
- Be able to be upgraded according to user needs
- Thumb-2 Technology: It extends 16-bit instructions of initial Thumb technology to 32-bit instructions. → Better performance than previously used Thumb technology.

These features along with many other advantages distinguish this processor from other ones for applications in portable devices like digital cameras, mobile phones, home networking modules and wireless communication technologies and other embedded systems.

Microprocessor without Interlocked Pipelined Stages (MIPS)



- Based on RISC architecture
- Large number of registers
- Visible pipeline delay slots
- High levels of power efficiency for today's SoC designs
- Able to port from one generation to the next while preserving their investment in existing software.
- Provides similar performance to MIPS32 with a code size reduction of up to 25%.

- Provides SIMD (Single Instruction Multiple Data operation), Virtualization, Multi-threading (MT) and DSP technologies.
- Single clock cycle

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21 arithmetic instructions (+, -, *, /, %)
8 logic instructions (&, |, ~)
8 bit manipulation instructions
12 comparison instructions (>, <, =, >=, <=, ¬)
25 branch/jump instructions
15 load instructions
10 store instructions
8 move instructions
4 miscellaneous instructions
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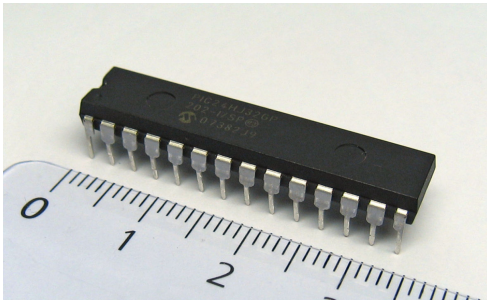
Programmable Interface Controllers (PIC) Microcontroller

- Based on Harvard architecture
- Low cost → Wide availability
- Simple interfacing capability with other auxiliary components
- Capacity for serial programming
- Small size



- The architecture entails I/O ports, CPU, A/D converter, interrupts, oscillator, counters/timers, memory organization CPP module and serial communication.
- Low power consumption

Due to its high speed and performance, it is used in audio accessories, peripherals, video games and electronic devices such as phones, computers and embedded Operating System.

AVR Microcontroller

It derives its name from its developers, Alf-Egil Bogen and Vegard Wollan. It is also known as Advanced Virtual RISC microcontroller.

- Mostly single execution cycle
- High speed
- Frequency range: [0 – 16] MHz
- Large memory
- Power efficiency
- Inbuilt ADC, timers and PWM channels
- 8-bit Register based

Intel Atom

This is an ultra-low-voltage processor by Intel Corporation designed to reduce electric consumption and power dissipation in comparison with ordinary processors of the Intel Core series. Atom is mainly used in netbooks, nettops, embedded applications ranging from health care to advanced robotics, mobile Internet devices (MIDs) and phones.

- Architecture: x86
- Socket: 437
- Transistor Count: 176 Million
- Manufacturing Technology: 45 nm
- Clock Rate: 1660 MHz
- TDP: 8.5 W
- Number of Cores/Threads: 2/4

Selecting a processor in the past was a much simpler task than it is today. There is a huge variety of processors, each one appropriate for a special purpose.

Microprocessors, Microcontrollers, Embedded processors, Media processors and Digital Signal processors are some types of processors.
Graphics processing units (GPUs) perform computer graphics operations, including linear algebra. Processors specialized for machine learning, fall under the category of AI accelerators also known as neural processing units (NPUs) and include vision processing units (VPUs) and Google's Tensor Processing Unit (TPU). Sound chips and sound cards are used for generating and processing audio. Image signal processors are DSPs specialized for processing images in particular. Physics processing units (PPUs) are built to efficiently make physics-related calculations, particularly in video games. Field-programmable gate arrays (FPGAs) are specialized circuits that can be reconfigured for different purposes. The Synergistic Processing Element or Unit (SPE or SPU) is a component in the Cell microprocessor.
Processors based on different circuit technology have been developed. One example is quantum processors, which use quantum physics to enable algorithms that are impossible on classical computers (those using traditional circuitry). Another example is photonic processors, which use light to make computations instead of semiconducting electronics.

As a conclusion, to select a processor especially for embedded purposes, one has to consider hardware departments as well as software components. Power consumption , Physical space, The ease of access and availability to the products in the market and The costs are some hardware related considerations. The performance of the processor, Memory and Peripherals are some software or architecture considerations.

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