A Survey of Various Processor Types and Design Architectures

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Abstract- This technical paper covers Evolution of processors, processor history, processor design trends, Modern Processor Architecture components, ARM based processor, Types of Processor- single cycle, multi cycle processor, Reduced Instruction set computer (RISC), Complex Instruction set computer (CISC), Very long instruction word (VLIW), Harvard and Von Neumann architecture.

Keywords- Instruction Set Architecture (ISA), RISC, CISC, Very Long Instruction Word (VLIW), Harvard, Von Neumann.

I. INTRODUCTION

A. Evolution of Processors

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First Generation Processor

First generation processors were used on the earliest machines, the original IBM PC and XT, and the first clones. These machines were primitive in most ways compared to modern PCs, and the processors used were of limited capabilities. First generation processors run at system bus speed and use the oldest processor technologies.

Second Generation Processor

The only chip generally considered second generation is the 80286. Intel also made a chip between the 8088 and the 80286, called the 80186. Due to lack of performance enhancements compared to the 286, in addition to compatibility problems with support chips, 80186 were not used in PCs.
Third Generation Processor

The third generation processors (the 386 family) represent another step forward from the second generation class. Intel started with this generation of chips to create "subfamilies" of related chips with different capabilities, using the "DX" and "SX" designations.

Fourth Generation Processor

- The fourth generation of processors saw rapid growth in the CPUs' power and capabilities.
- Also, it was at this time that the new phenomenon of upgradable processors and standardized motherboard sockets began to become prevalent.
- Some fourth Generation Processors are: - INTEL 80486DX, INTEL 80486SX, INTEL 80486DX2 & INTEL 80486DX2 overdrive, INTEL 80486DX4 & INTEL 80486DX4 overdrive, AMD 5x86, Cyrix 5x86.

Fifth Generation Processor

- The fifth generation of processors saw several changes from earlier CPU families; architectural changes were made to increase the overall system speed. AMD and Cyrix developed their own compatible processors, leading to more variety and choice in the marketplace. The Pentium and the compatibles that followed it opened up the world of computers for millions of users and propelled computing to the next level.
- Some examples are Intel Pentium (“P5”/ “P54C”), Intel Pentium over drive, Intel Pentium with MMX technology, Intel Pentium with MMX technology over drive, Cyrix 6x86, AMD K5 [1].

B. Processor History

The below graph is the Moore’s law progression from 1970 to 2020 against number of transistors per integrated circuit.
The above graph indicates average of Rmax/socket, average of cores per socket and average of Rmax/core from the year 1996 to 2014.

Graph shows the number of cores, typical power, frequency, sequential processor performance, parallel processor performance and number of transistors for different processors.

Moore’s Law – Today’s Status

The above graph shows the Moore’s law according to which- The number of transistors on a chip tends to double for every 2 years.

C. Processor Design trends

A central processing unit (CPU) is the electronic circuit within a computer that performs the basic arithmetic, logical, control and input/output (I/O) operations specified by the instructions.
**D. Modern Processor Architecture components**
- Major components of a computer
  - Central Processing Unit (CPU)
  - memory
  - peripheral devices
- Architecture is concerned with
  - internal structures of each
  - interconnections
    - speed and width
    - relative speeds of components
- Want maximum execution speed
  - Balance is often critical issue
- CPU
  - performs arithmetic and logical operations
  - synchronous operation
  - may consider instruction set architecture
    - how machine looks to a programmer
    - detailed hardware design

**E. ARM-based System**

**F. Processor Architecture**
G. Processor Classification

- Single cycle
- Multi Cycle Processor

A single cycle processor executes each instruction in one cycle. The instruction is fetched from memory, it is executed, and the results are stored all in a single clock cycle [2]. The advantage of single-cycle processors is that they have simple hardware requirements, and they are easy to design. But they have poor data throughput, and require long clock cycles (slow clock rate) to perform all the necessary computations in time.
I. Classification based on Instruction type

Instruction Set Architecture (ISA)

- The instruction set architecture ISA refers to the programmer visible instruction set.
  - It defines the boundary between hardware and software.
- Often the ISA is identified with the processor architecture.
- The processor microarchitecture refers to the internal organization of the processor.
  - So, several specific processors with differing microarchitectures may share the same architecture, i.e. the same ISA.
- Complex Instruction Set Computer (CISC)
- Reduced Instruction Set Computer (RISC)
- Very Long Instruction Word (VLIW)

Very Long Instruction Word (VLIW)

VLIW is a computer processing architecture in which a compiler or pre-processor breaks the program instruction into basic operations that can be performed by the processor in parallel. It uses a long instruction word that contains fixed number of instructions that are fetched, decoded, issued, and executed synchronously [4].

- Very Long Instruction Word (VLIW) architectures store several simple instructions in one long instruction fetched from memory
  - Number and type are fixed
  - E.g., 2 memory reference, 2 floating point, one integer
- Need one functional unit for each possible instruction
  - 2 fp units, 1 integer unit, 2 MBRs
  - All run synchronized
- Each instruction is stored in a single word
  - Requires wider memory communication paths
  - Many instructions may be empty, meaning wasted code space
- One instruction contains several independent operations that are executed in parallel
- Instruction level parallelism
- Rely on the compiler to determine which instruction may be executed in parallel
- The number of operations in VLIW instruction is equal to the number of execution units in the processor
- Widely used in DSP applications
  - High performance and low cost

Advantages
- Simpler and Faster than RISC
- VLIW machines uses less complicated logic to check for dependencies.
- Eliminates complicated instruction scheduling and parallel dispatch associated with superscalar approach

Disadvantages
- Increased code size due to empty “slots”
- Incremental in execution unit => the program must be recompiled
- Increased memory bandwidth (IBM prototype has 759-bit instructions)
- Compiler is critical to performance: must do all dependency resolution
- Cache miss in one pipeline will force all pipelines to stall in a “pure” VLIW machine
- Actual hardware “shows through” – source recompile needed to run on new machine
### Harvard Architecture

The Harvard architecture is a kind of storage of data. The main function of this architecture is physical storage of the data and provides the signal pathways for instruction and data [6]. It has two separate memory - Program memory and Data memory. The architecture is able to read an instruction and it can also perform data memory access simultaneously at high speed. Used in MCS-51, MIPS etc.

#### Advantages

- Two memories with two buses allow parallel access to data and instructions. Execution can be 2x faster.
- Both memories can be produced by different technology (Flash/EEPROM, SRAM/DRAM).
- Both memories can use different cell sizes.
- Program can't rewrite itself.

#### Disadvantages

- Control unit for two buses is more complicated and more expensive.
- Production of a computer with two buses is more expensive.
- Development of a complicated Control Unit needs more time. - Free data memory can't be used for instruction and vice-versa [6].

### Von Neumann Architecture

The Von Neumann architecture is a computer architecture that uses a processing unit and a single separate storage structure to hold both instructions and data. Example: 8086 architecture.

#### Advantages

- Control unit gets data and instruction in the same way from one memory.
- It simplifies the design and development of the Control Unit.
- Data from memory and the devices are accessed in the same way.
- Memory organization is in the hands of programmers.
Disadvantages

- Serial instruction processing does not allow parallel execution of program. Parallel executions are simulated later by the Operating system.
- It has one bus and hence only single information can be accessed at a time.
- Instruction stored in the same memory as the data can be accidentally rewritten by an error in a program [6].

II. CONCLUSION

As a part of my ongoing research on design and development of next generation processors, it is necessary to understand the history and evolution of various processors, their architecture, functionalities, specifications, and special features the way these processors have been designed, their advantages, disadvantages and applications.

This technical survey paper covers only 30% of the total data that I have collected in last 3 years. My upcoming papers will give more content on processor types & design architecture.

REFERENCES

[1] PROCESSOR FAMILIES by Prabhanshu Tripathi and Ankit Gupta