Computer Architecture: The Conceptual Evolution

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Lecture 1

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Designing a Large Computer

- We need a machine which could perform computation: Addition, Subtraction, Multiplication, Division, Exponential operation, etc.. Additionally: Logic operations like and, or, xor, complement etc.

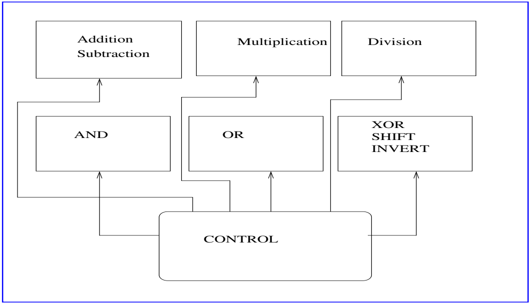


Figure : Something like this is needed! We call it processing unit

A Theoretical Foundation: Turing Machine

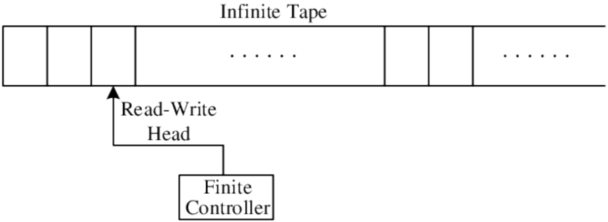


Figure : Theoretical Turing Machine Model

- Three things to note: Memory (ability to remember), Processing, And Control
- How does this led to a physical computer?

The Von Neumann Architecture

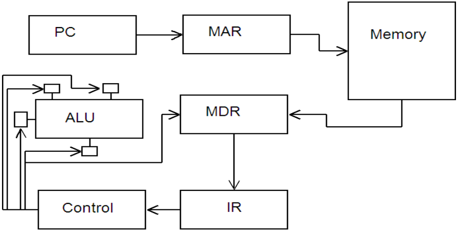


Figure : Von Neumann Architecture

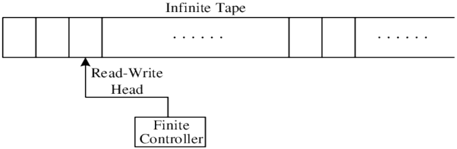


Figure : Theoretical Turing Machine Model

The Von Neumann Architecture

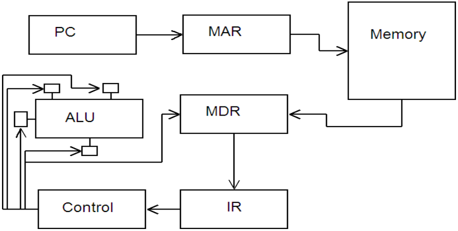


Figure : Von Neumann Architecture

ALU: for the purpose processing the data
Memory: To keep something (data and instruction) for sufficient amount of time
Control: The one who manages the communication between ALU and Memory

PC: Program counter
MDR: Memory data register
MAR: Memory address register

IR: Instruction register

The Von Neumann Architecture: What do you do?

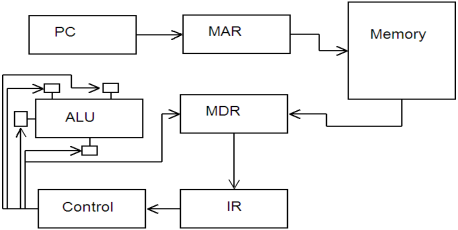


Figure : A machine which dances in the tune of ISA

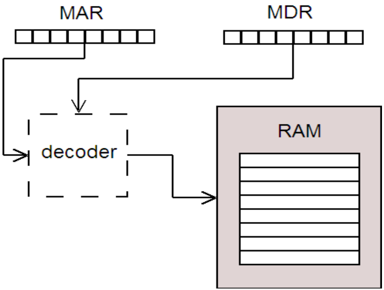
Definition: A program is defined as a well defined or meaningful collection of instructions from ISA.

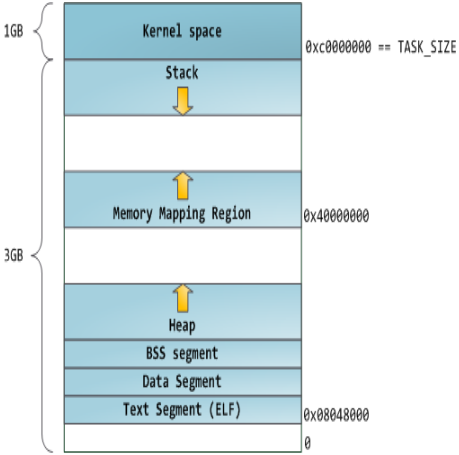
```
push    %rbp
mov     %rsp,%rbp
push    %r12
push    %rbx
mov     %edi,-0x14(%rbp)
mov     %rsi,-0x20(%rbp)
mov     $0xa,%ebx
mov     $0x14,%r12d
add     %r12d,%ebx
mov     %ebx,%eax
sub     %r12d,%eax
mov     %eax,%r12d
sub     %r12d,%ebx
mov     $0x0,%eax
pop     %rbx
pop     %r12
pop     %rbp
retq
```

Figure : A program

How and Where do the program reside

Storing to Memory





What If the program size is too big?

What if the program size is too big?
What if the power goes off?

- A large memory is needed
- A permanent storage is needed
- Therefore the secondary storage
- How do the Secondary storage and the primary memory communicate: Address space, virtual memory and address translation needs to be investigated

A Computer is Now Designed

- It is now functionally correct, a programmer is able to write program, keep it in memory, and process it to get the desired output.
- We want more!
- Better performance at lesser cost

Two ways to get better at lesser:

1. One: An individual would do a single work a bit faster
2. Two: An individual/group would do a multiple work together

Designer and architect approach:

1. One: An individual would do a single work a bit faster: increase the clock frequency
2. Two: An individual would do a multiple work together: execute the instructions in parallel

How to Execute Instruction Parallel?

ADD R1 R2 R3

Lets see what happen to a single instruction?

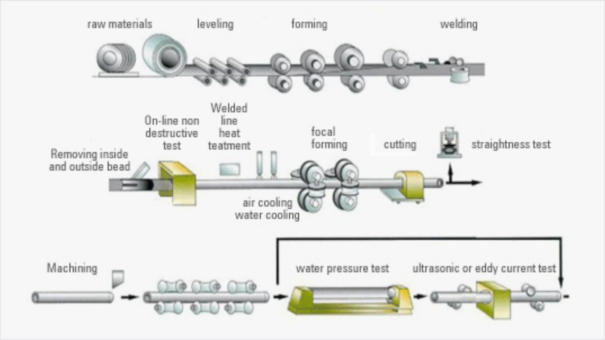


Figure : Manufacturing unit pipeline

Pipeline Architecture

ADD R1 R2 R3

Lets see what happen to a single instruction?

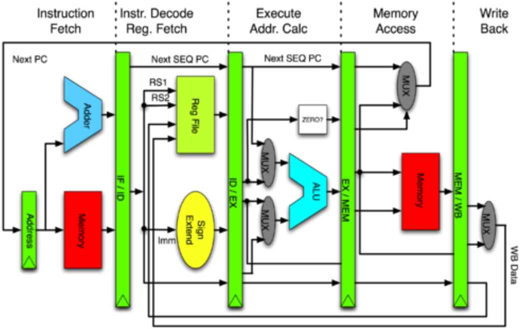
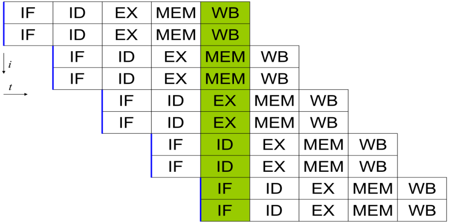


Figure : Processor pipeline

Can We Do better?

Many pipelines in parallel?



IF	ID	EX	MEM	WB				
IF	ID	EX	MEM	WB				
	IF	ID	EX	MEM	WB			
	IF	ID	EX	MEM	WB			
		IF	ID	EX	MEM	WB		
		IF	ID	EX	MEM	WB		
			IF	ID	EX	MEM	WB	
			IF	ID	EX	MEM	WB	
				IF	ID	EX	MEM	WB
				IF	ID	EX	MEM	WB

Figure : Superscalar pipeline architecture

How pipelines in parallel?

Soon we realized that there are not enough parallel instructions!

Other form of parallel architecture

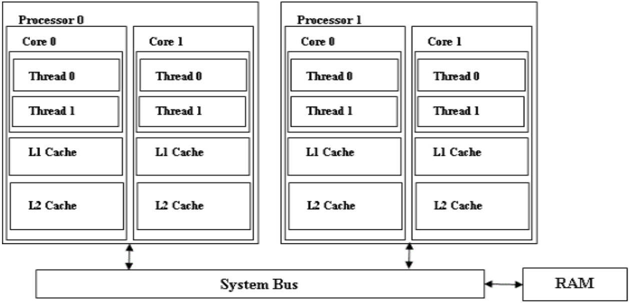


Figure : Multicore-multithreaded-multiprocessor Architecture

The foundation behind the parallel architecture is breaking the dependencies

Another Important Observation

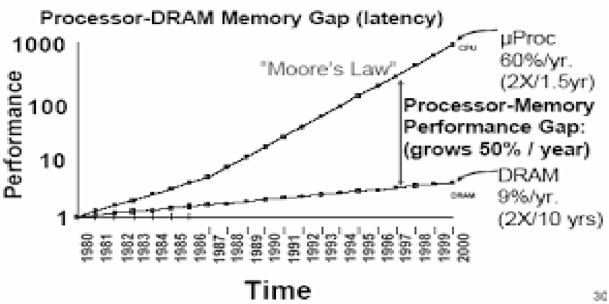


Figure : Processor Memory Performance Gap

The gape is increasing!
What to do?

Faster Memory closer to Processor

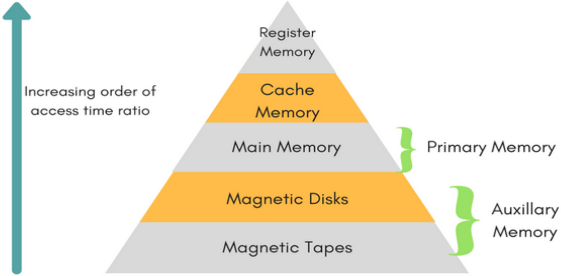


Figure : Memory Hierarchy: smaller the faster the costlier

Many researches are still active in this domain!

Lecture 2

Computer Architecture: study of performance?

Thank You