IA-32 Architecture

Computer Organization and Assembly Languages
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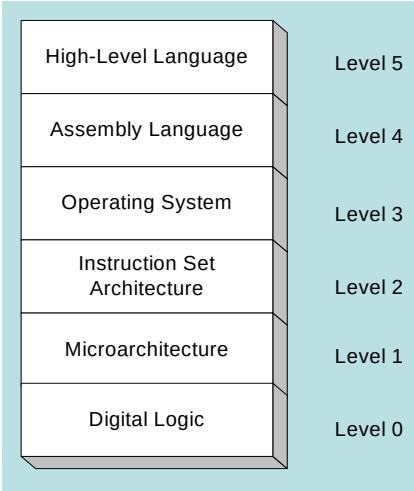
2005/09/29

with slides by Kip Irvine and Keith Van Rhein

Virtual machines

Abstractions for computers

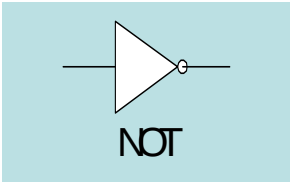


NOT

- Inverts (reverses) a boolean value
- Truth table for Boolean NOT operator:

X	¬X
F	T
T	F

Digital gate diagram for NOT:

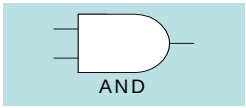


AND

- Truth if both are true
- Truth table for Boolean AND operator:

X	Y	X ∧ Y
F	F	F
F	T	F
T	F	F
T	T	T

Digital gate diagram for AND:

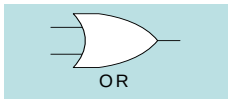


OR

- True if either is true
- Truth table for Boolean OR operator:

X	Y	X ∨ Y
F	F	F
F	T	T
T	F	T
T	T	T

Digital gate diagram for OR:



Truth tables

- A Boolean function has one or more Boolean inputs, and returns a single Boolean output.
- A truth table shows all the inputs and outputs of a Boolean function

Example: ¬X ∨ Y

X	¬X	Y	¬X ∨ Y
F	T	F	T
F	T	T	T
T	F	F	F
T	F	T	T

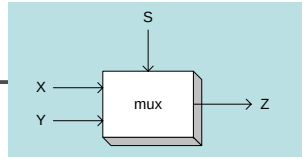
All possible 2-input Boolean functions

0 0 0 0	0	0
0 0 0 1	AND	
0 0 1 0	xy'	
0 0 1 1	x	x
0 1 0 0	x'y	
0 1 0 1	y	y
0 1 1 0	XOR	
0 1 1 1	OR	

1 0 0 0	NOR	
1 0 0 1	XNOR	
1 0 1 0	y'	y
1 0 1 1	x + y'	
1 1 0 0	x'	x
1 1 0 1	x'+y	
1 1 1 0	NAND	
1 1 1 1	1	1

Truth tables

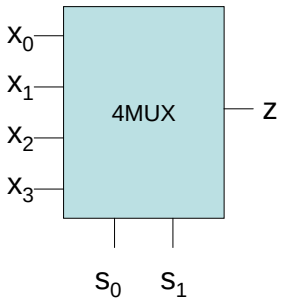
- Example: (Y ∧ S) ∨ (X ∧ ¬S)

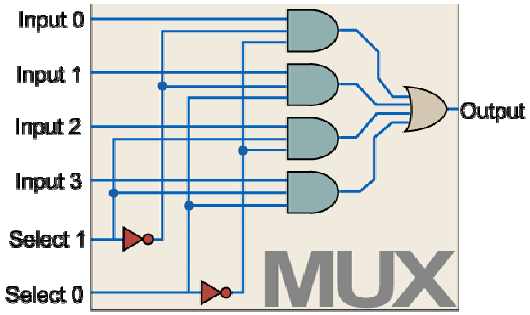


Two-input multiplexer

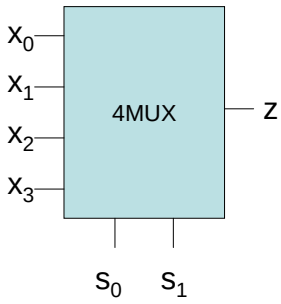
X	Y	S	Y ∧ S	¬S	X ∧ ¬S	(Y ∧ S) ∨ (X ∧ ¬S)
F	F	F	F	T	F	F
F	T	F	F	T	F	F
T	F	F	F	T	T	T
T	T	F	F	T	T	T
F	F	T	F	F	F	F
F	T	T	T	F	F	T
T	F	T	F	F	F	F
T	T	T	T	F	F	T

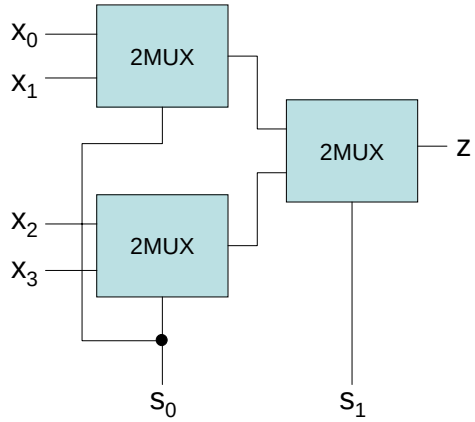
4-multiplexer



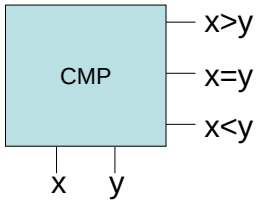


4-multiplexer



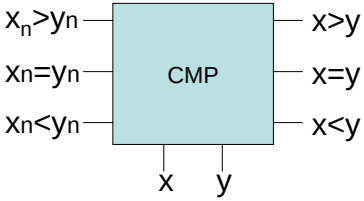


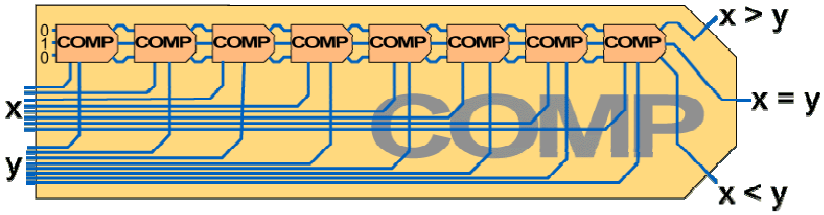
Comparator



x	y	x>y	x=y	x<y

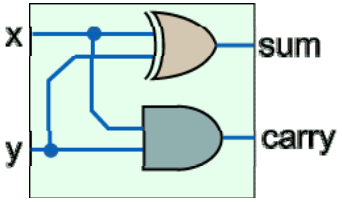
8-bit comparator



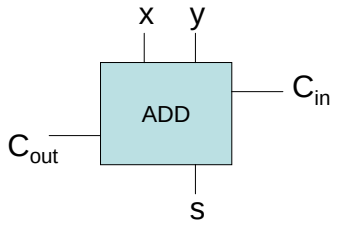


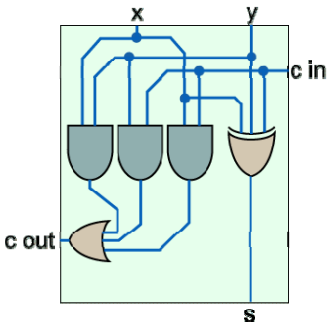
1-bit half adder

x	y	s	c



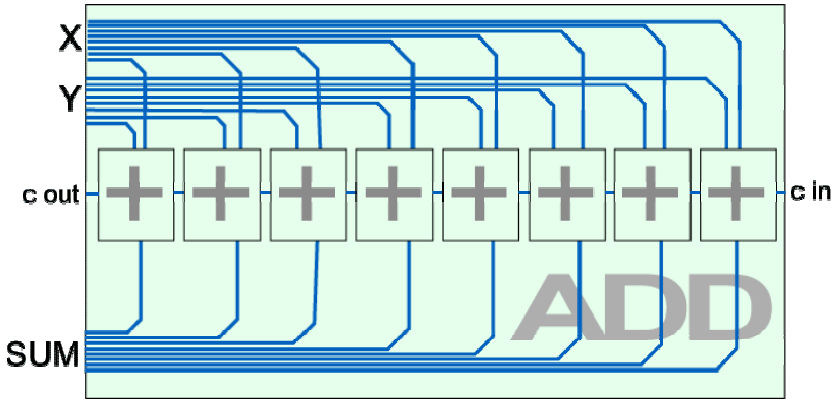
1-bit full adder



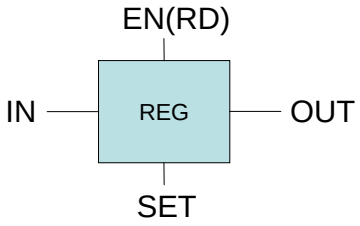


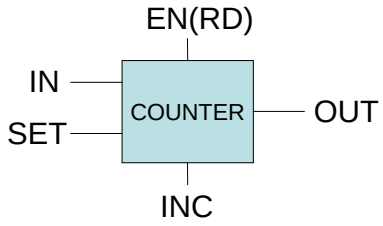
x	y	C_{in}	C_{out}	s

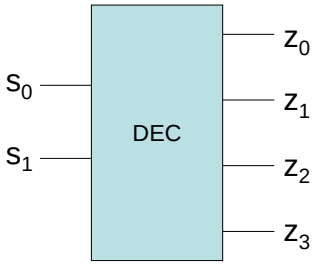
8-bit adder



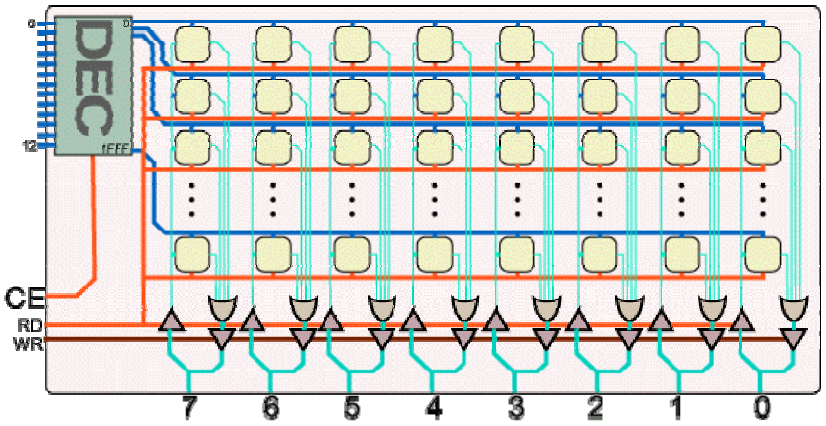
Registers and counters







Memory

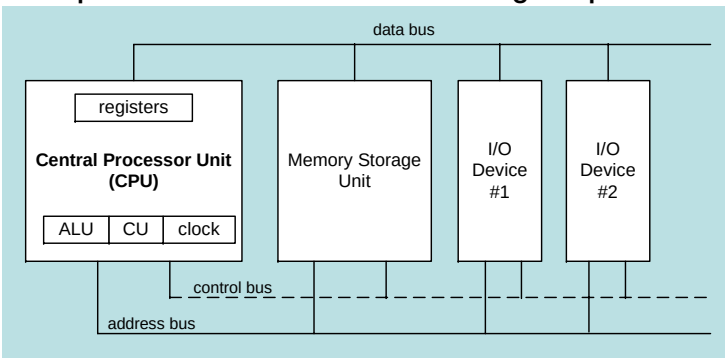


8K 8-bit memory

Microcomputer concept

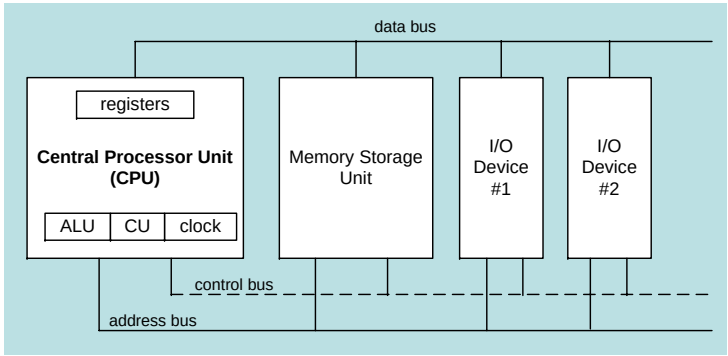
Basic microcomputer design

- clock synchronizes CPU operations
- control unit (CU) coordinates sequence of execution steps
- ALU performs arithmetic and logic operations



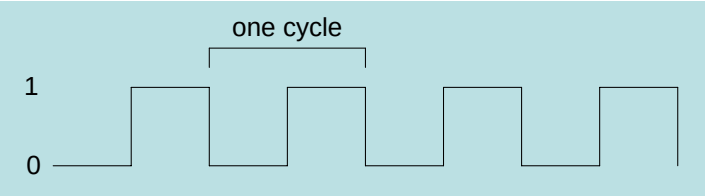
Basic microcomputer design

- The memory storage unit holds instructions and data for a running program
- A bus is a group of wires that transfer data from one part to another (data, address, control)



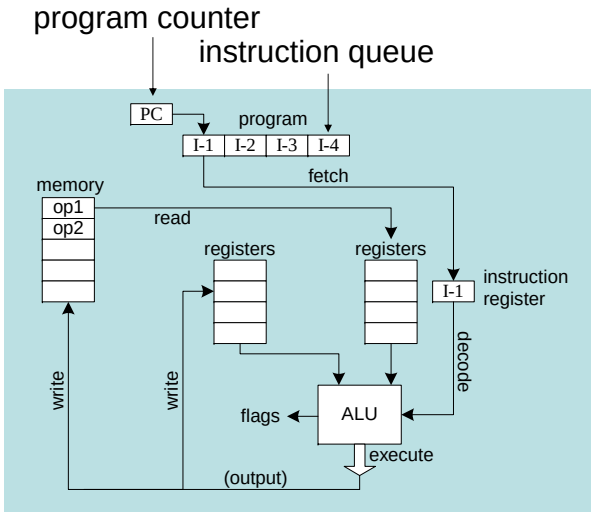
Clock

- synchronizes all CPU and BUS operations
- machine (clock) cycle measures time of a single operation
- clock is used to trigger events



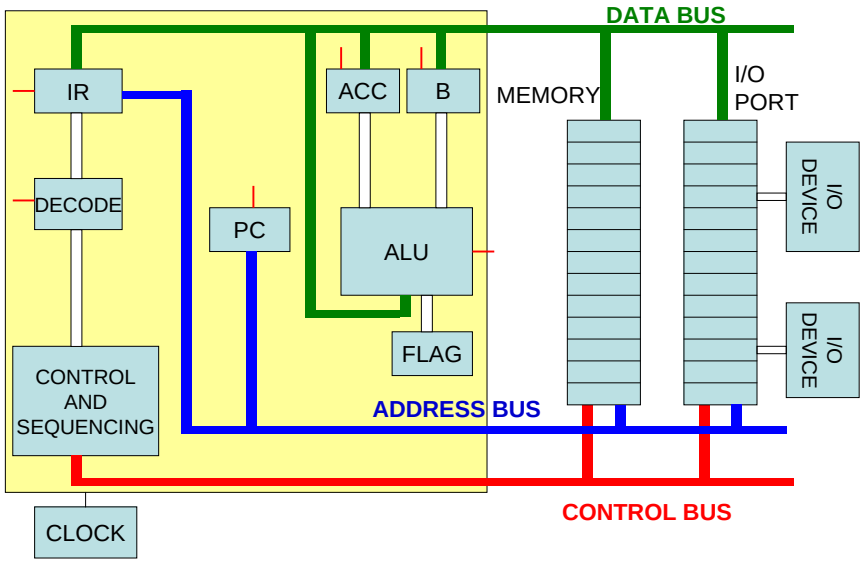
- Basic unit of time, 1GHz→clock cycle=1ns
- A instruction could take multiple cycles to complete, e.g. multiply in 8088 takes 50 cycles

Instruction execution cycle



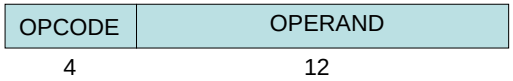
- **Fetch**
- **Decode**
- Fetch operands
- **Execute**
- Store output

A simple microcomputer



Instruction set

OPCODE	MNEMONIC	OPCODE	MNEMONIC
0	NOP	A	CMP
1	LDA	B	JG
2	STA	C	JE
3	ADD	D	JL
4	SUB		
5	IN		
6	OUT		
7	JMP		
8	JN		
9	HLT		

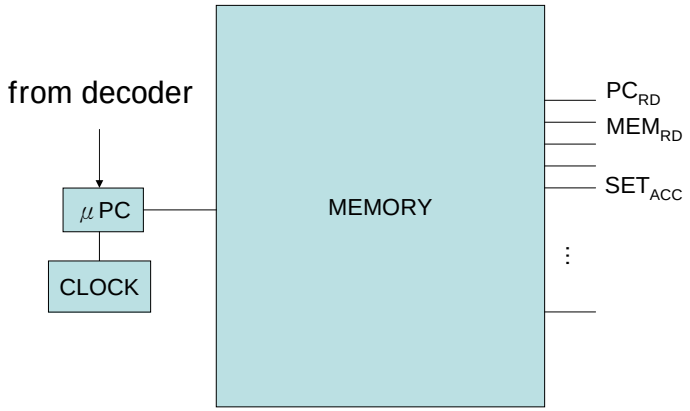


Control bus

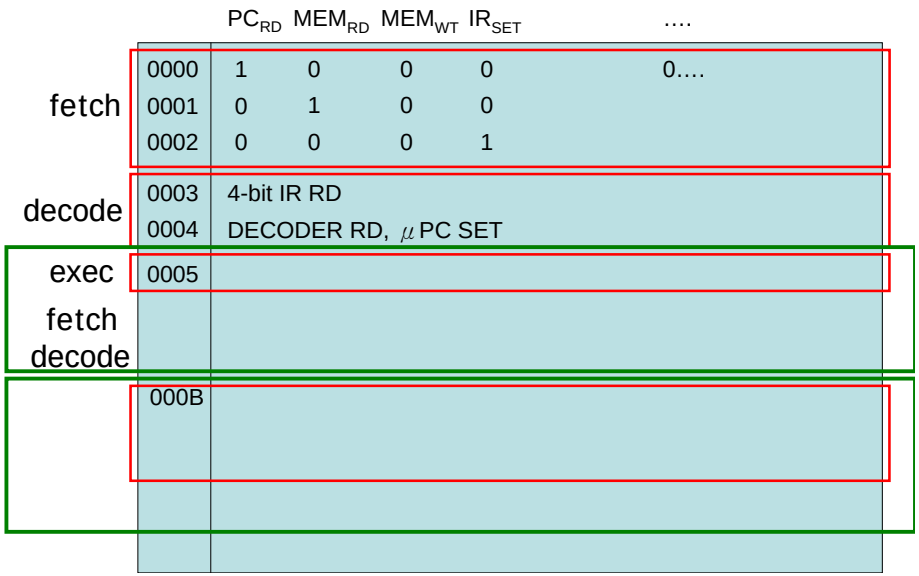
- A series of control signals to control all components such as registers and ALU
- Control signal for load ACC:

  SET_{ACC}=1, others=0

Control and sequencing unit



Control and sequencing unit



Decoder