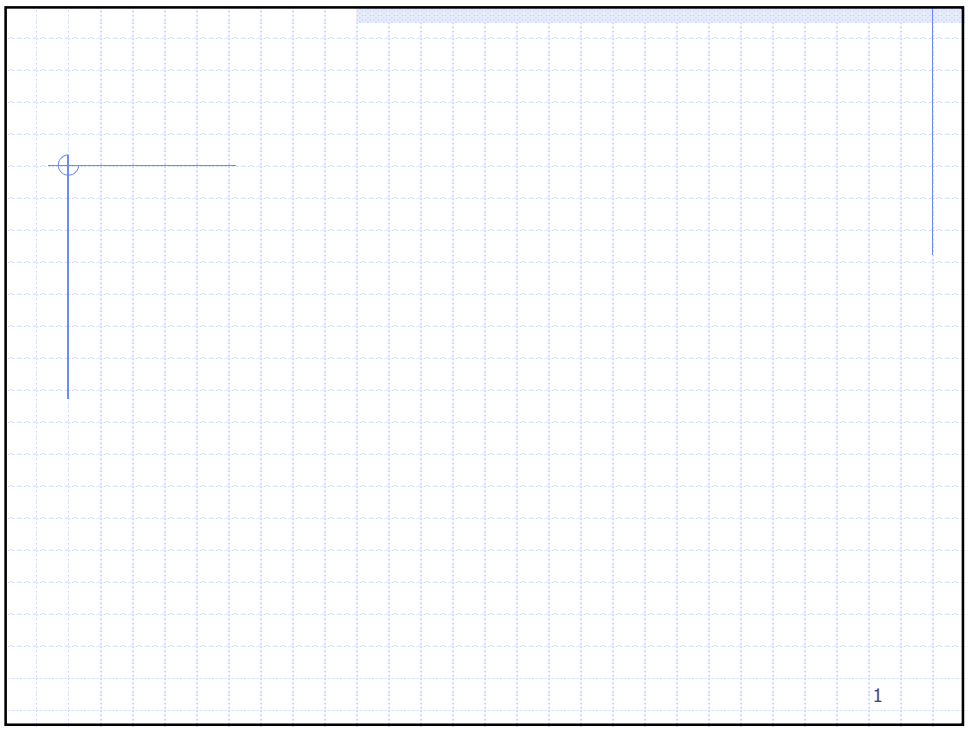
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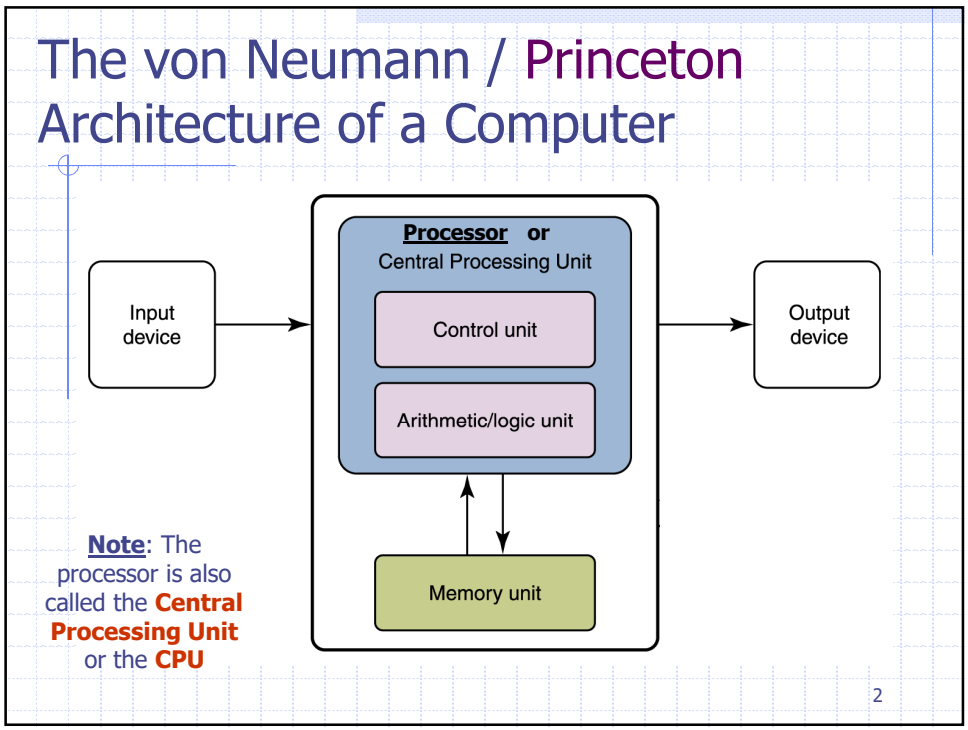

The von Neumann / Princeton Architecture of a Computer
Processor or
Central Processing Unit
Control unit
Arithmetic/logic unit
Memory unit
Input device
Output device
Note: The processor is also called the Central Processing Unit or the CPU
2

2

Von Neumann Architecture

There are 3 major units in a computer tied together by buses:

1) Memory The unit that stores and retrieves instructions and data.

2) Processor: The unit that houses two separate components:

The control unit: Repeats the following 3 tasks

Fetches an instruction from memory

Decodes the instruction

Executes the instruction

The arithmetic/logic unit (ALU): Performs mathematical and logical operations.

3) Input/Output (I/O) Units: Handle communication with the outside world.

3

3

Von Neumann Architecture

The architecture is named after the mathematician, John von Neumann, who supposedly proposed storing instructions in the memory of a computer and using a control unit to handle the fetch-decode-execute cycle:

fetch an instruction

decode the instruction

execute the instruction

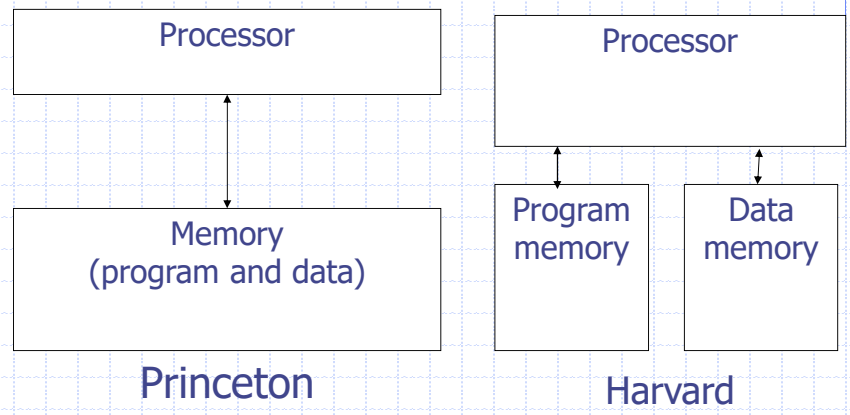
Although we think of data being stored in a computer, in reality, both data and instructions are stored there.

4

4

Two Memory Architectures

- von Neumann /Princeton
  - Fewer memory wires
- Harvard
  - Simultaneous program and data memory access



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Flow of Information

- The parts are connected to one another by a collection of wires called a bus

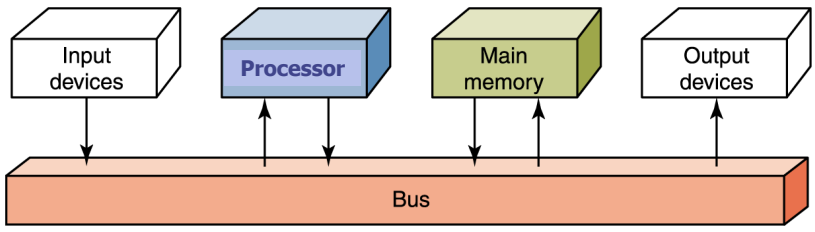


Figure 5.2 Data flow through a von Neumann architecture

6

6

Babbage

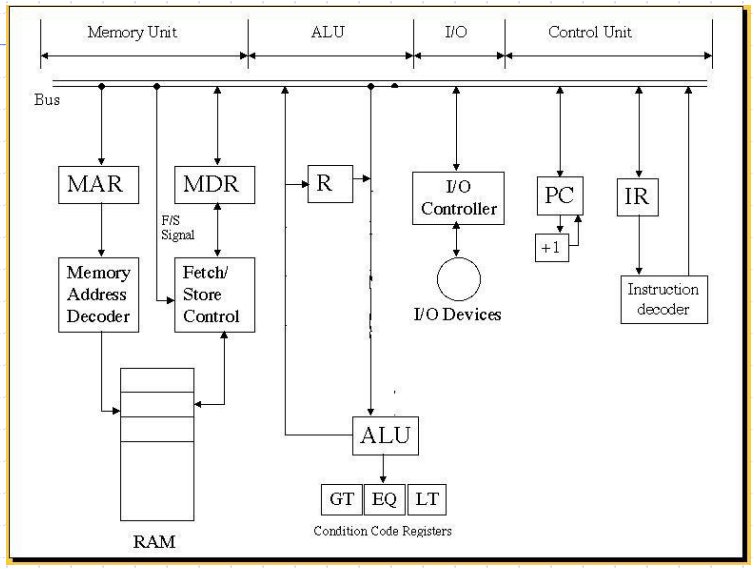
Interestingly, a similar architecture was proposed in 1830 by Charles Babbage for his Analytic Engine:

ALU	mill
memory	store
control unit	operator (process cards storing instructions)
I/O units	output (typewriter)

7

7

More Detail on Computer Architecture



8

8

Memory

- Memory is a collection of cells, each with a unique physical address
- The size of a cell is normally a power of 2, typically a byte.

Address	Contents
00000000	11100011
00000001	10101001
⋮	⋮
11111100	00000000
11111101	11111111
11111110	10101010
11111111	00110011

9

9

Memory

- A cell is the smallest addressable unit of memory – i.e. one cell can be read from memory or one cell can be written into memory, but nothing smaller.

Address	Contents
00000000	11100011
00000001	10101001
⋮	⋮
11111100	00000000
11111101	11111111
11111110	10101010
11111111	00110011

10

10

RAM and ROM

- RAM stands for **Random Access Memory**
  - Inherent in the idea of being able to access each location is the ability to change the contents of each location
- ROM stands for **Read Only Memory**
  - The contents in locations in ROM cannot be changed
- RAM is volatile, ROM is not
  - This means that RAM does not retain its bit configuration when the power is turned off, but ROM does

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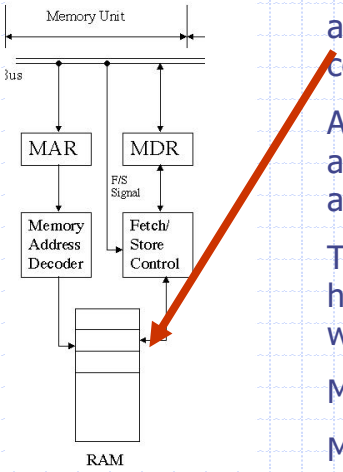
MEMORY UNIT
(or RAM- Random Access Memory)



Each cell has an address, starting at 0 and increasing by 1 for each cell.

A cell with a low address is just as accessible as one with a high address- hence the name RAM.

The width of the cell determines how many bits can be read or written in one machine operation.

MAR is Memory Address Register

MDR is Memory Data Register

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What is a Register?

- Data can be moved into and out of registers faster than from memory.
- If we could replace all of memory with registers, we could produce a very, very fast computer ...
- But, the price would be terribly prohibitive.
- Most computers have quite a few registers that serve different purposes.
- We'll see how the MAR and the MDR are used.

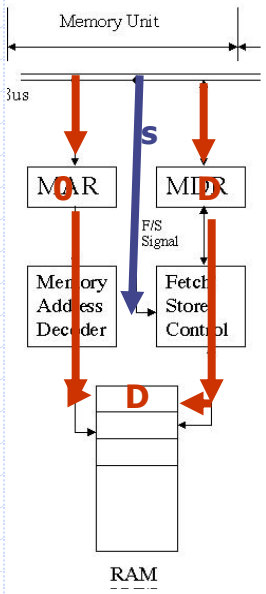
13

13

How does the memory unit work?

Trace the following operation:

Store data D in memory location 0.



14

How does the memory unit work?

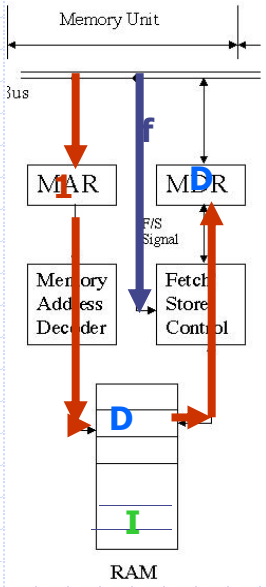
Trace the following operation:

1) Fetch data D from memory location 1.

2) Obtain an instruction I from memory location 7.

How does the computer distinguish between 1) and 2) above?

We need to look at the control unit later.



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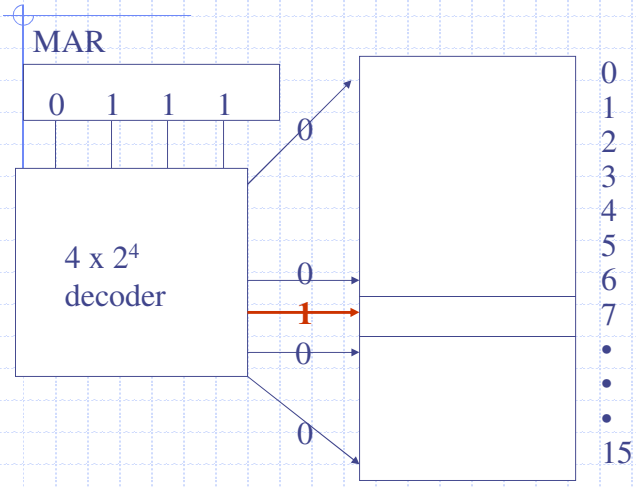
USING THE DECODER CIRCUIT TO SELECT MEMORY LOCATIONS



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The decoder circuit doesn't scale well--- i.e. as the number of bits in the MAR increases, the number of output lines for the decoder goes up exponentially.

Most computers today have an MAR of 32 bits. Thus, if the memory was laid out as we showed it, we would need a 32 x 2^{32} decoder!

Note 2^{32} is $2^2\ 2^{30} = 4$ G

So most memory is not 1 dimensional, but 2-dimensional (or even 3-dimensional if banked memory is used).

17

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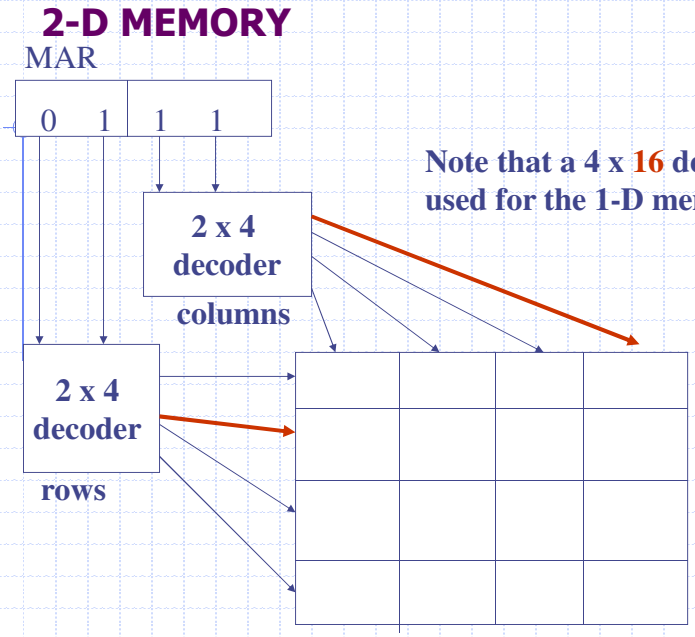
2-D MEMORY



18

18

Arithmetic/Logic Unit (ALU)

- Performs basic arithmetic operations such as adding
- Performs logical operations such as AND, OR, and NOT
- Most modern ALUs have a small amount of registers where the work takes place.
- For example, adding A and B, we might find A stored in one register, B in another, and their sum stored in, say, A, after the adder computes the sum.

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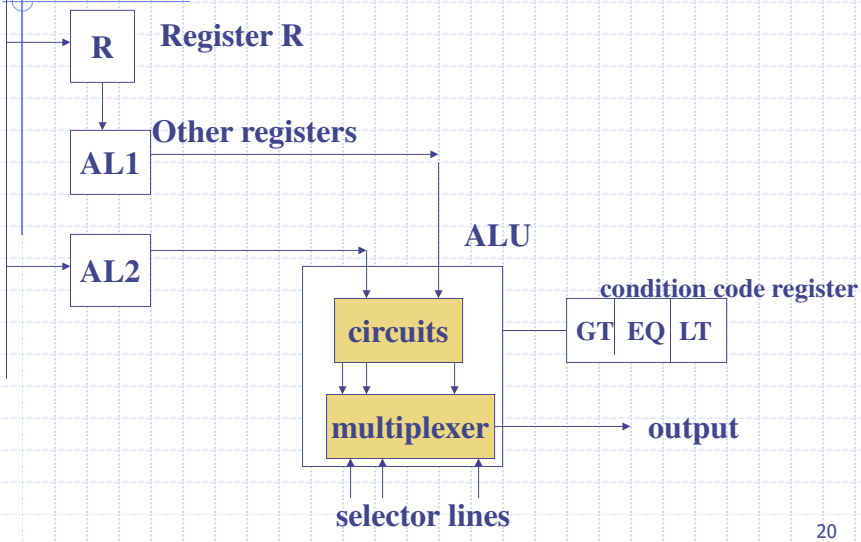
The ALU Uses a Multiplexer



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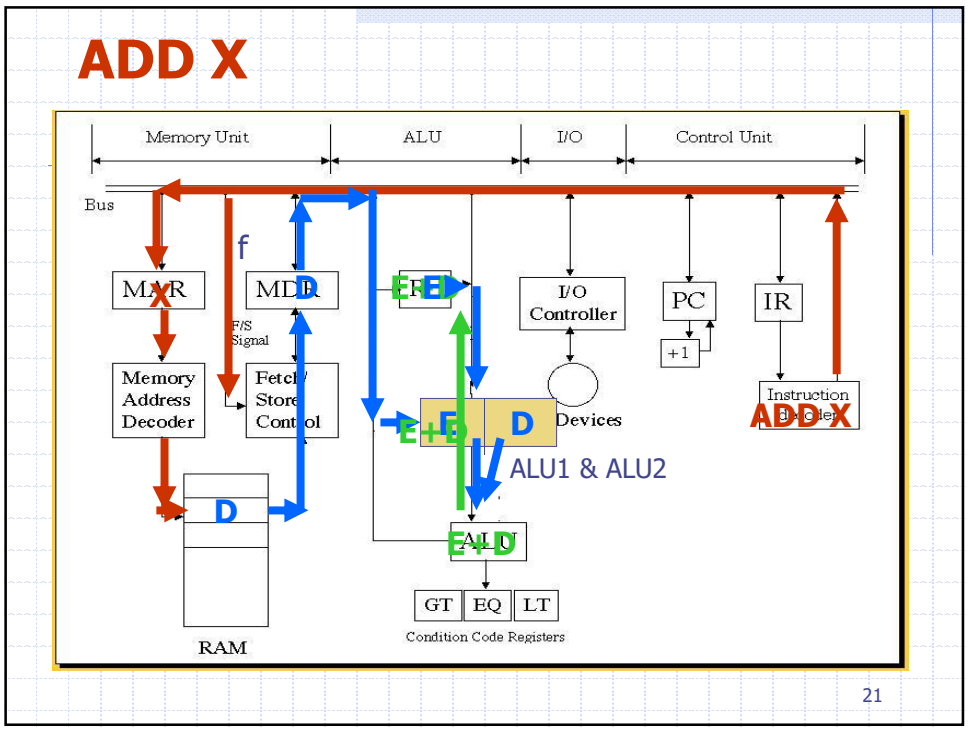

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Control Unit

- A Control Unit is the unit that handles the central work of the computer.
- There are two registers in the control unit
  - The instruction register (IR) contains the instruction that is being executed
  - The program counter (PC) contains the address of the next instruction to be executed
- The ALU and the control unit together are called the Central Processing Unit, or CPU

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ALL A COMPUTER DOES IS …

- Repeat forever (or until you pull the plug or the system crashes)
- 1) FETCH (the instruction)
- 2) DECODE (the instruction)
- 3) EXECUTE (the instruction)

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The Fetch-Execute Cycle

- Fetch the next instruction
- Decode the instruction
- Execution Cycle
  - Gets data if needed
  - Execute the instruction

Normally "Get data if needed" is considered part of the "Execute the instruction".

24

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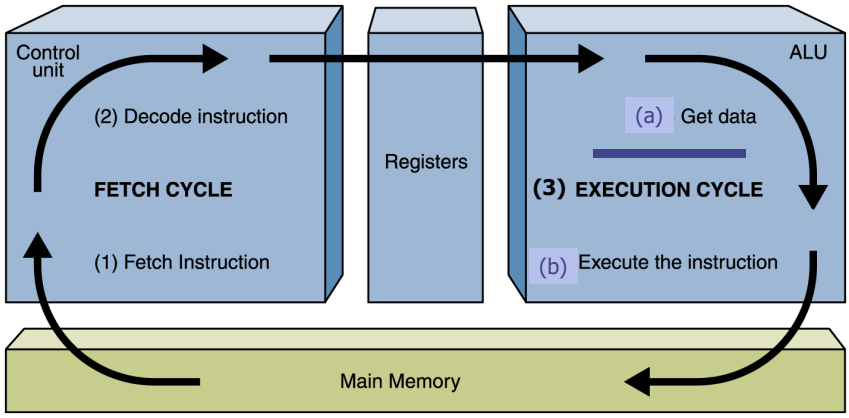
Figure 5.3 The Fetch-Execute Cycle



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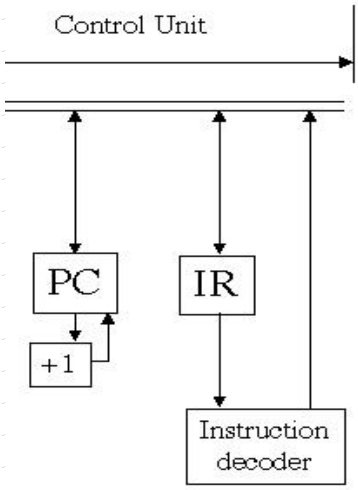
25

How Does the Control Unit Work?

Once the instruction is fetched, the PC is incremented.



The PC holds the address of the next instruction to be executed.

Whatever is stored at that address is assumed to be an instruction.

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26

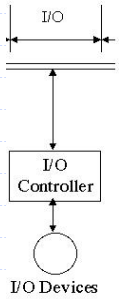
Input/Output Units

- An input unit is a device through which data and programs from the outside world are entered into the computer
  - Keyboard, the mouse, and scanning devices
- An output unit is a device through which results stored in the computer memory are made available to the outside world
  - Printers and video display terminals

27

27

THE I/O DEVICES



Pictorially, these look the simplest, but in reality, they form the most diverse part of a computer.

Includes:

keyboards, monitors, joysticks, mice, tablets, lightpens, spaceballs, ...

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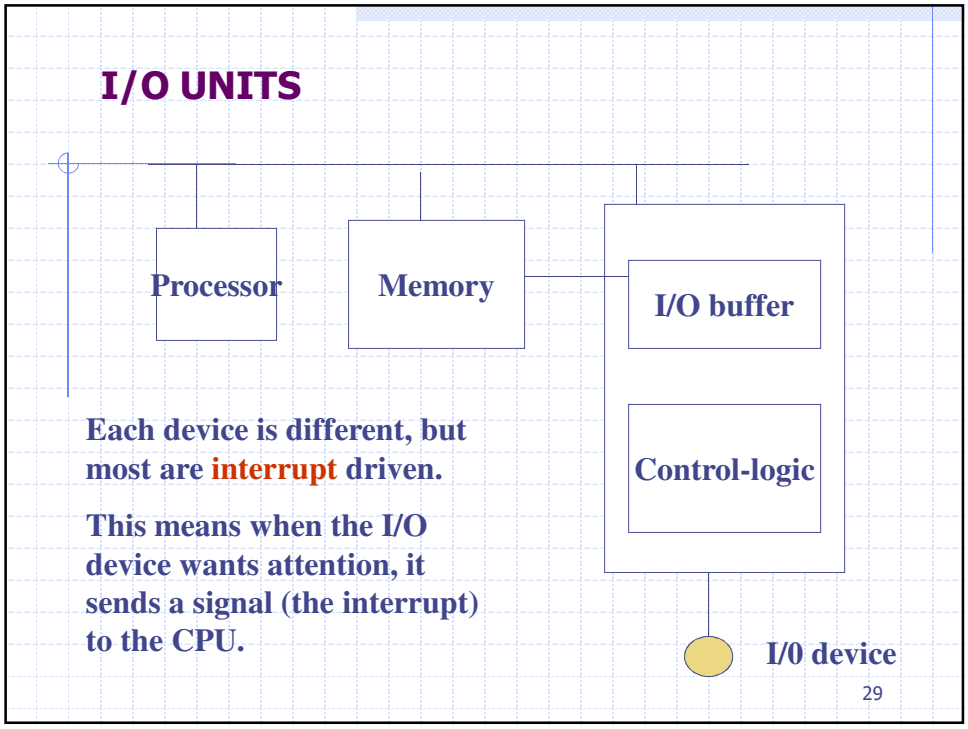
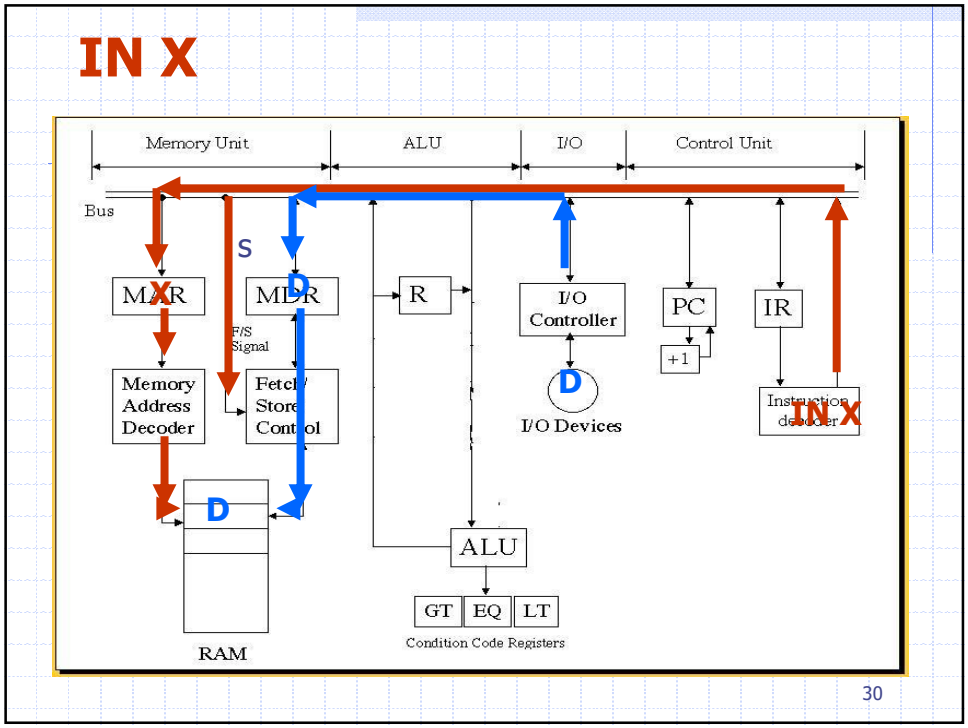
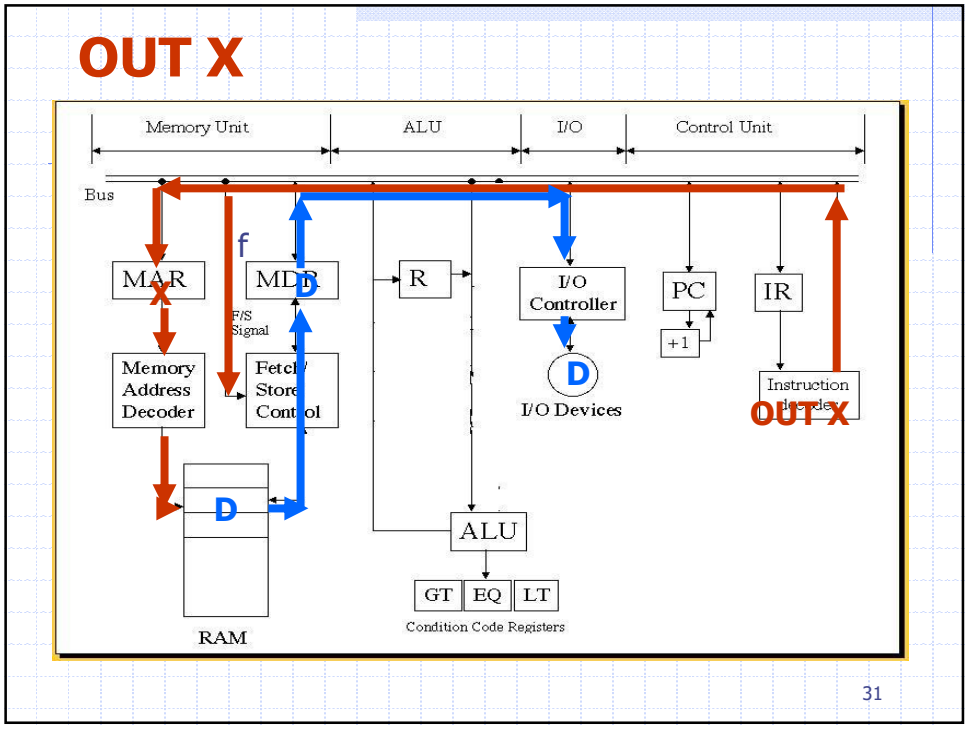

I/O UNITS
Processor
Memory
I/O buffer
Control-logic
I/0 device
Each device is different, but most are interrupt driven.
This means when the I/O device wants attention, it sends a signal (the interrupt) to the CPU.
29

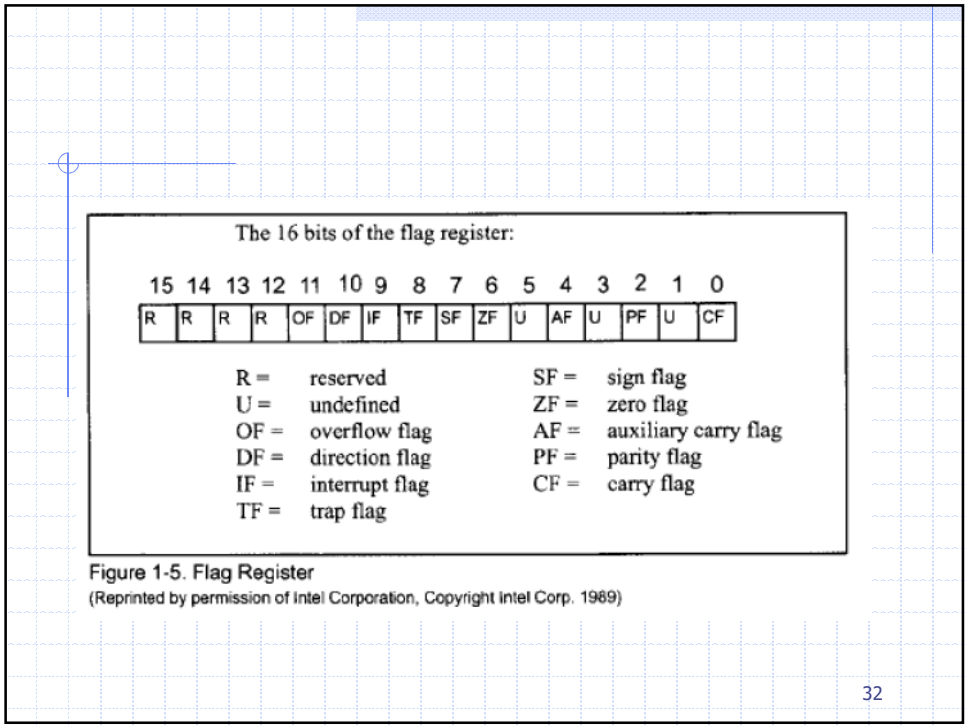
29


IN X
Memory Unit
ALU
I/O
Control Unit
Bus
S
D
MAR
MDR
R
I/O Controller
PC
IR
F/S Signal
+1
Memory Address Decoder
Fetch/ Store Control
D
I/O Devices
Instruction decoder
IN X
D
ALU
GT
EQ
LT
Condition Code Registers
RAM
30

30


OUT X
Memory Unit
ALU
I/O
Control Unit
Bus
f
MAR
MDR
R
I/O Controller
PC
IR
+1
F/S Signal
Memory Address Decoder
Fetch/ Store Control
D
I/O Devices
Instruction
OUT X
D
ALU
GT
EQ
LT
Condition Code Registers
RAM
31

31


The 16 bits of the flag register:
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
R R R R OF DF IF TF SF ZF U AF U PF U CF
R = reserved
U = undefined
OF = overflow flag
DF = direction flag
IF = interrupt flag
TF = trap flag
SF = sign flag
ZF = zero flag
AF = auxiliary carry flag
PF = parity flag
CF = carry flag
Figure 1-5. Flag Register
(Reprinted by permission of Intel Corporation, Copyright Intel Corp. 1989)
32

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8051 Microcontroller Internal RAM

- 16 Bytes are bit addressable (16*8=128)
- Rest will be accessed in byte format

33

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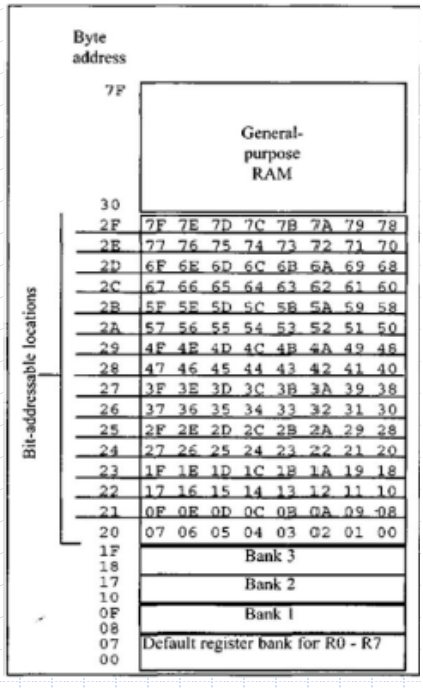

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