Announcements

Project 2B turn-in Wednesday 11:00PM

Midterm 2 on Friday

Only on material since last midterm

Computer Basics

How exactly does a computer work?
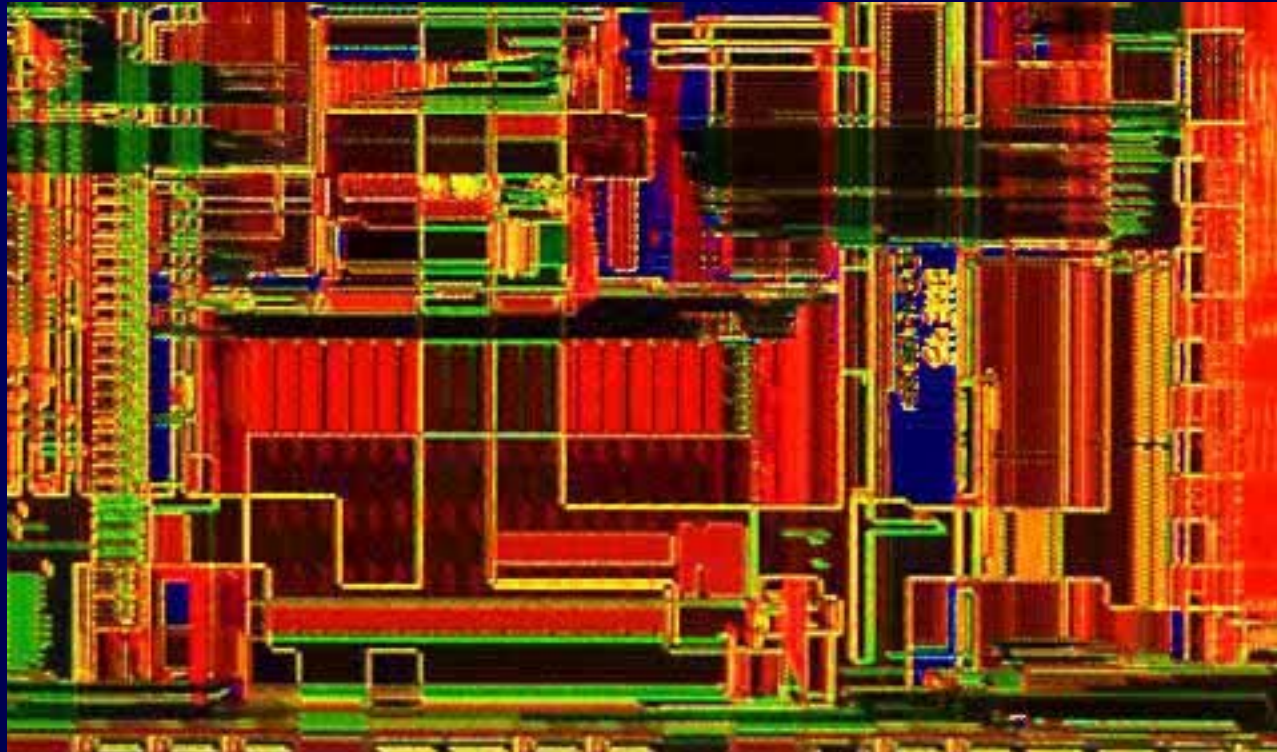
Integrated Circuits

Integrated circuits (ICs) are the power source of the information revolution

- When computers were made of discrete parts, wires of every transistor (3), capacitor (2), resistor (2), etc. had to be hand-connected
- Labor intensive, expensive, error prone, unreliable, cumbersome, … even with robots!
- Integrated circuits solved that by 2 ideas

  Integration -- circuits built as a unit from like parts
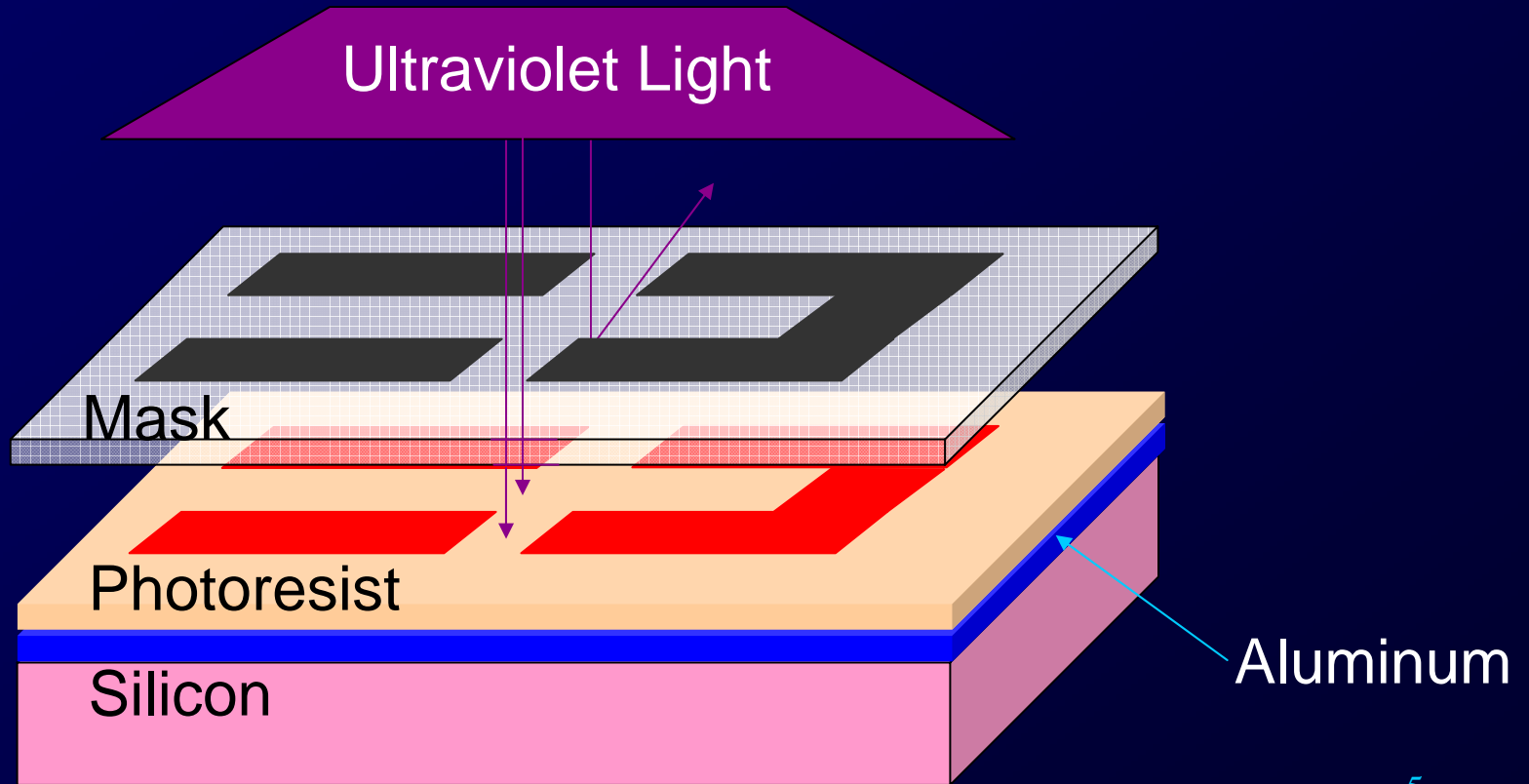
  Photolithography -- printing process to make chips

Intel Pentium Processor
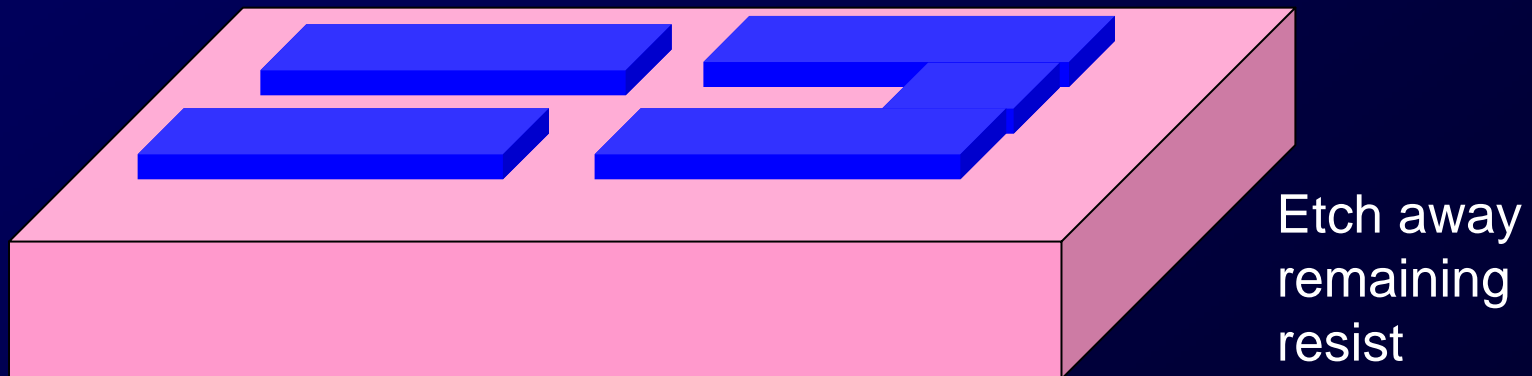
Photolithography

Consider process for depositing wires

Ultraviolet Light

Mask

Photoresist

Silicon

Aluminum

5

Remove Resist

Etch away changed-by-light resist
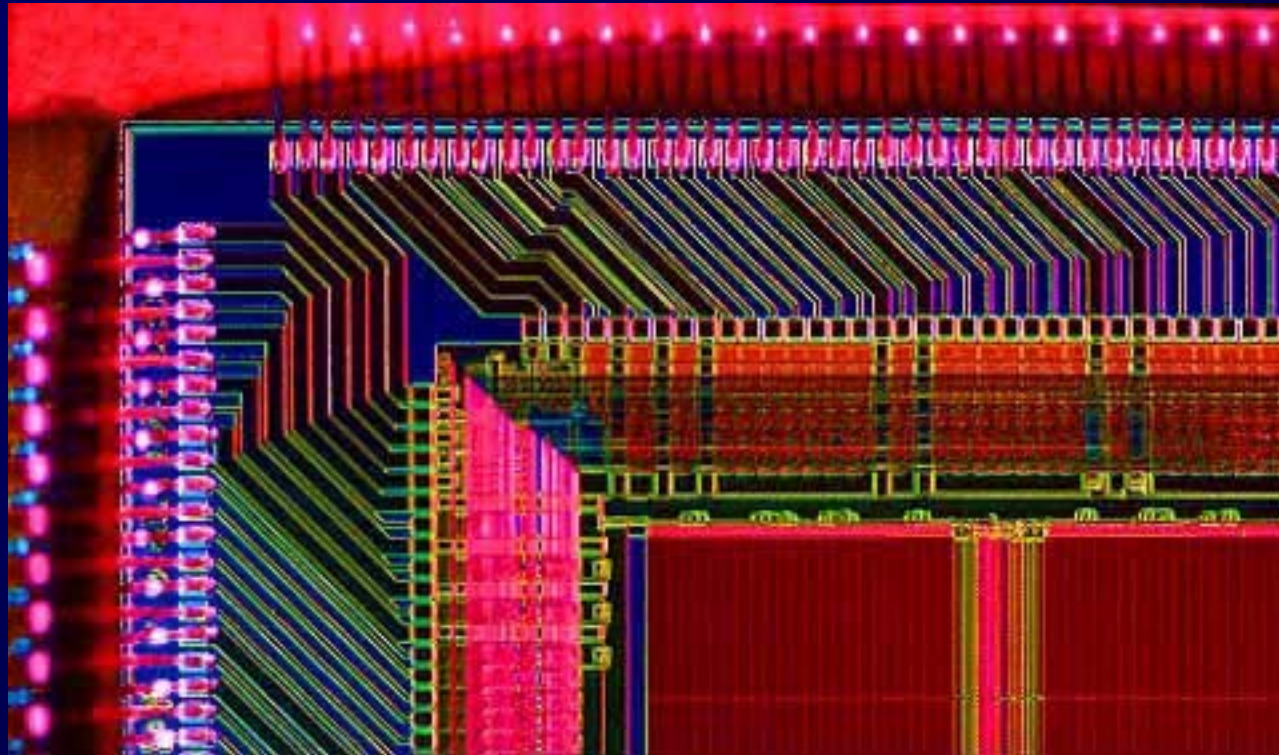
Etch away remaining resist
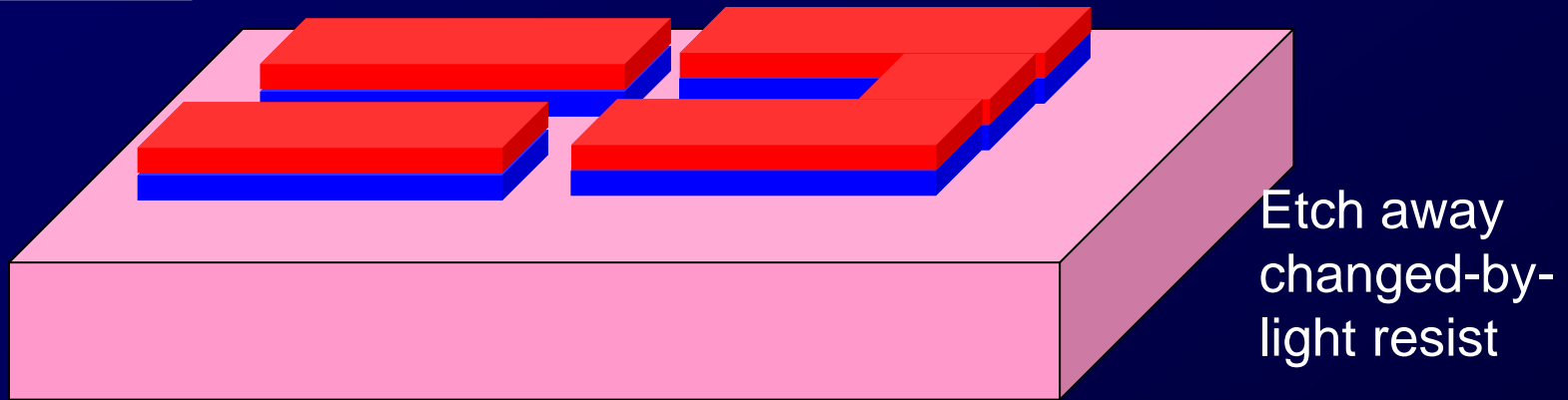
The cost of the circuit is not related to complexity

R4400 NEC/MIPS Procesor

Semiconductors

Silicon, a semiconductor -- sometimes it conducts and sometimes it doesn't

- It's possible to control when semiconductors do and don't conduct

Compute by controlling conducting

Ex.: Use control to test (`Mars AND rover`)

Make semiconductor conduct
if "Mars" is found

Make semiconductor conduct
if "rover" is found

Send "yes" signal on wire

Detect presence/absence of "yes"

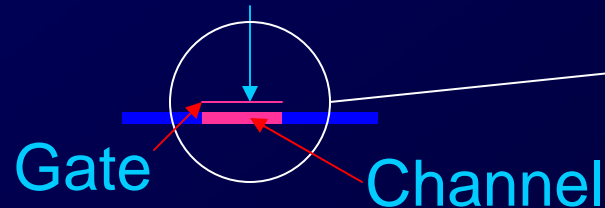# Field Effect

Charged objects are familiar -- use a nylon comb on a dry day

- **A charged field can control whether a semiconductor conducts or not**

A transistor has 3 wires

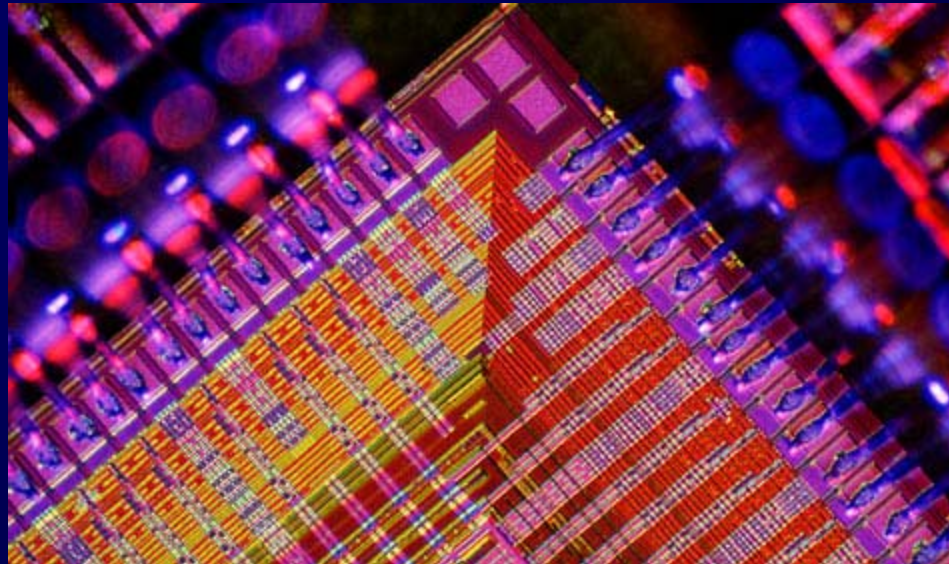Gate   Channel

The charge of the control wire (gate) is key

- Neutral gate, channel doesn't conduct
- Charged gate, channel conducts

MIPS R10000 Processor

Notice that wires cross over other wires ...

MOS Transistors

The field effect idea is implemented in metal-oxide-semiconductor transistors

Insulator

Gate

Wire

Wire

Channel

Silicon
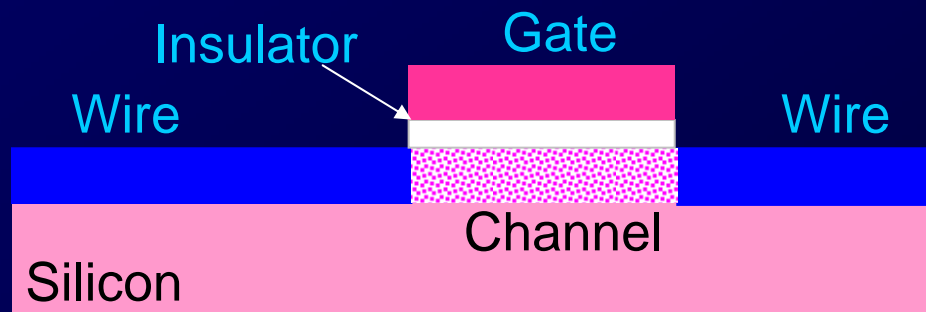
Cross section view
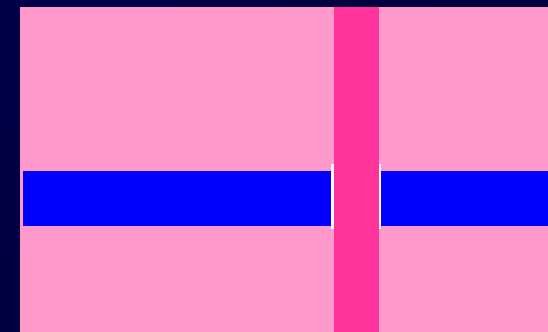
View from above

Operation

The two cases: the gate is neutral or the gate is charged

Gate

Wire | Wire

Channel

+ + Gate + +

Wire | Wire
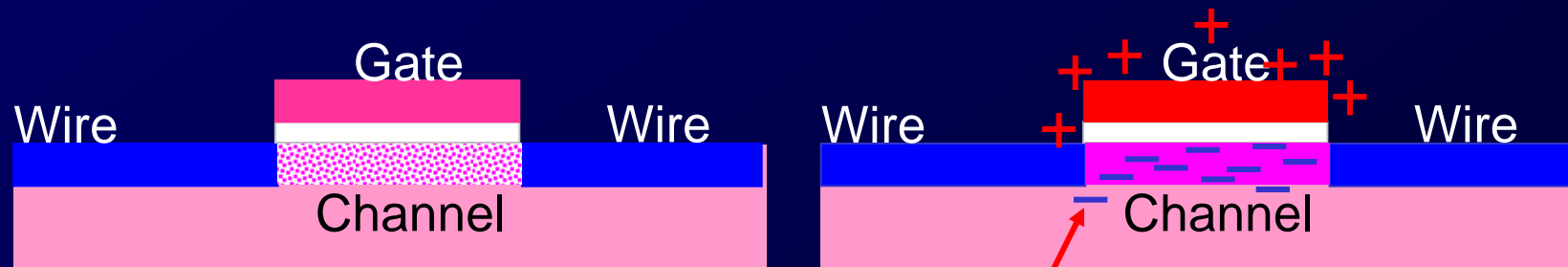
Channel

Charged gate attracts electrons to channel

Notice key points of integrated circuits:
Constructed as a unit of compatible parts
Fabricated in layers by photolithography

Computers ...

Deterministically execute instructions to process information

"Deterministically" means that when a computer chooses the next instruction to perform it is required by its construction to execute a specific instruction based only on the program and input it is given

Computers have no free will and they are not cruel

Fetch/Execute Cycle

Computer = instruction execution engine

- The fetch/execute cycle is the process that executes instructions

Instruction Fetch (IF)
Instruction Decode (ID)
Data Fetch (DF)
Instruction Execution (EX)
Result Return (RR)

Anatomy of a Computer

ALU

Control

Input — Mouse, Keyboard, Scanner

Hard Disk
Floppy Disk

Memory

Output — Monitor, Printer, Speakers
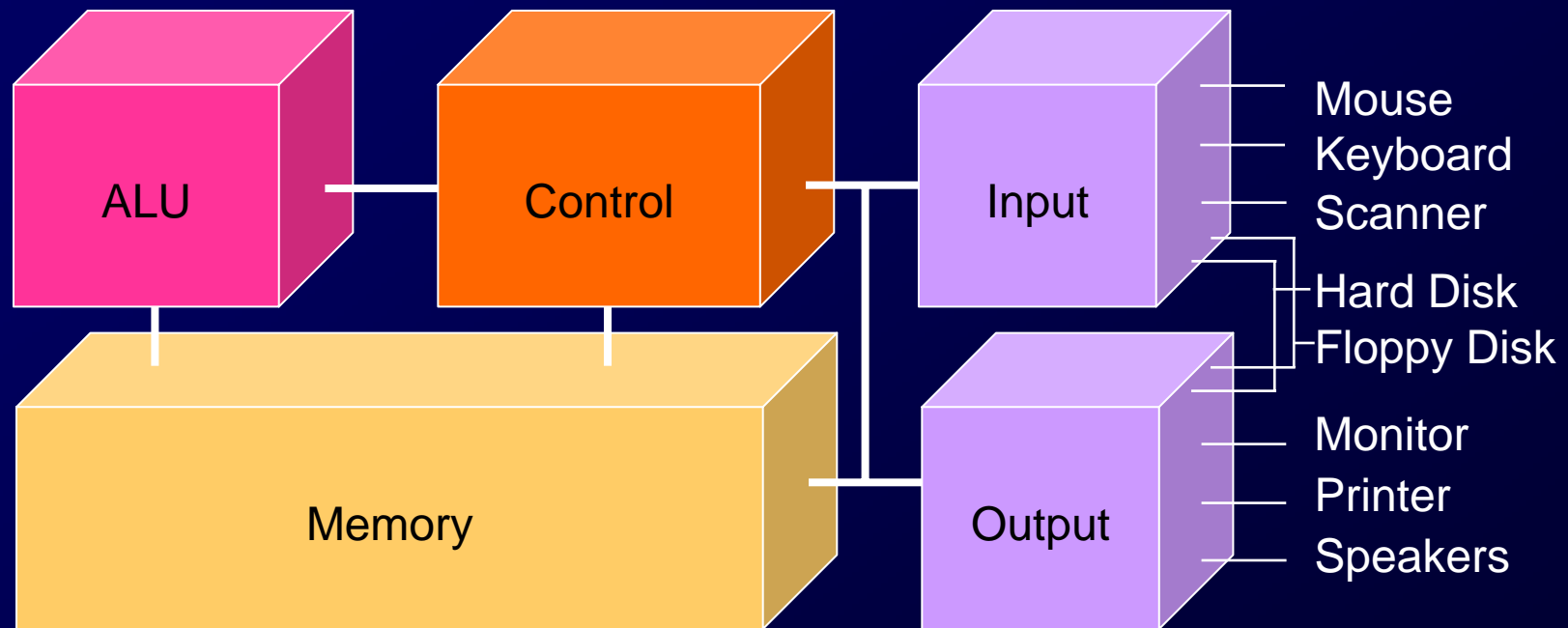
The Hard Disk is the α-device

Memory ...

Programs and their data must be in the memory while they are running

Memory locations

memory addresses

0	1	2	3	4	5	6	7	8	9	10	11
	G	o	D	a	w	g	s	!	!	0		...

memory contents

byte=8 bits

0	1	0	0	0	1	0	0
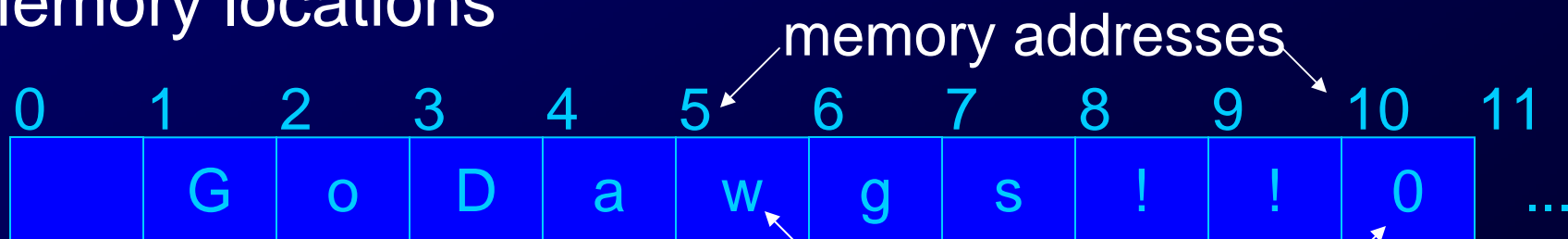
Groups of four bytes are a *word*

Control

The Fetch/Execute cycle is hardwired into the computer's control, i.e. it is the actual "engine"

The instructions executed have the form
ADDB 20, 10, 16

10	11	12	13	14	15	16	17	18	19	20	21
6						12				18	

...

Put in memory location 20 the contents of memory location 10 + contents of memory location 16

Indirect Data Reference

Instructions tell *where* the data is, not *what* the data is … contents change

One instruction has many effects
ADDB 20, 10, 16

10	11	12	13	14	15	16	17	18	19	20	21
8						7				15	...

10	11	12	13	14	15	16	17	18	19	20	21
60						-55				5	...

ALU

The Arithmetic/Logic Unit does the actual computation

Each type of data has its own separate instructions

ADDB : add bytes ADDBU : add bytes unsigned
ADDH : add half words ADDHU : add halves unsigned
ADD : add words ADDU : add words unsigned
ADDS : add short decimal numbers
ADDD : add long decimal numbers

Most computers have only about a 100-150 instructions hard wired

Input/Output

Input units bring data to memory from outside world; output units send data to outside world from memory

- Most peripheral devices are "dumb" meaning that the processor assists in their operation
- Disks are *memory* devices because they can output information and input it back again

The PC's PC

The program counter (PC) tells where the next instruction comes from

- **Instructions are a word long, so add 4 to the PC to find the next instruction**

Program Counter:	112

110	111	112	113	114	115	116	117	118	119	120	121
688,724		ADD 210,216,220				AND 414,418,720				OR	...

Clocks Run The Engine

The rate a computer "spins around" the Fetch/Execute cycle is controlled by it's clock

- Current clocks run 2-3 GHz
- In principle, the computer should do one instruction per cycle, but often it fails to
- Modern processors try to do more than one instruction per cycle, and often succeed

Clock rate is not a good indicator of speed

Summary

Semiconductors make Info Revolution

* Semiconductors properties …

  Fields controls when semiconductor conducts

  On/off of conductors allows us to compute

Fetch/execute cycle runs instructions

* 5 steps to interpret machine instructions
* Programs must be in the memory
* Data is moved in and out of memory

Instructions, data are represented in binary